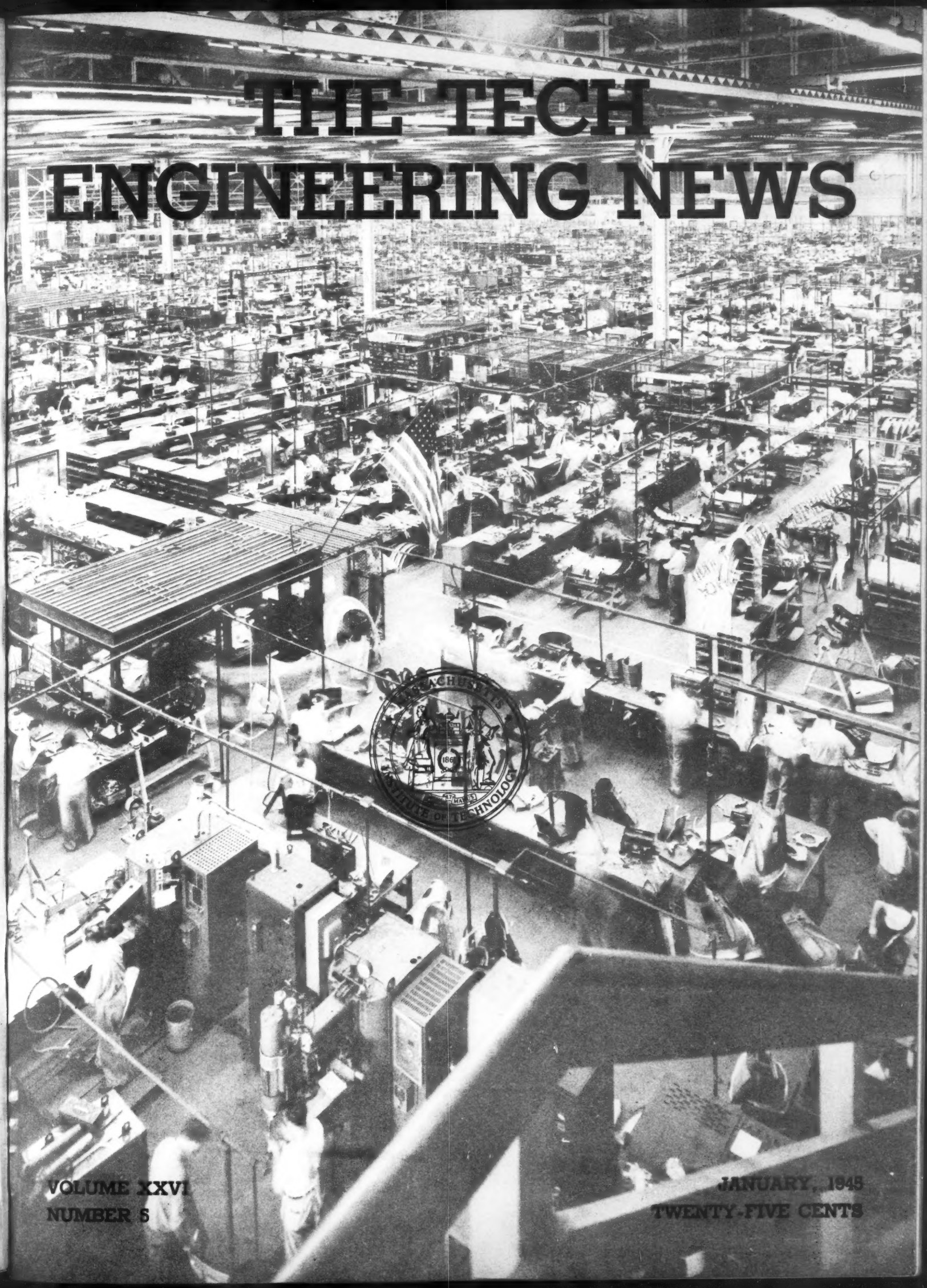
THE TECH ENGINEERING NEWS



VOLUME XXVI
NUMBER 5

JANUARY, 1945
TWENTY-FIVE CENTS

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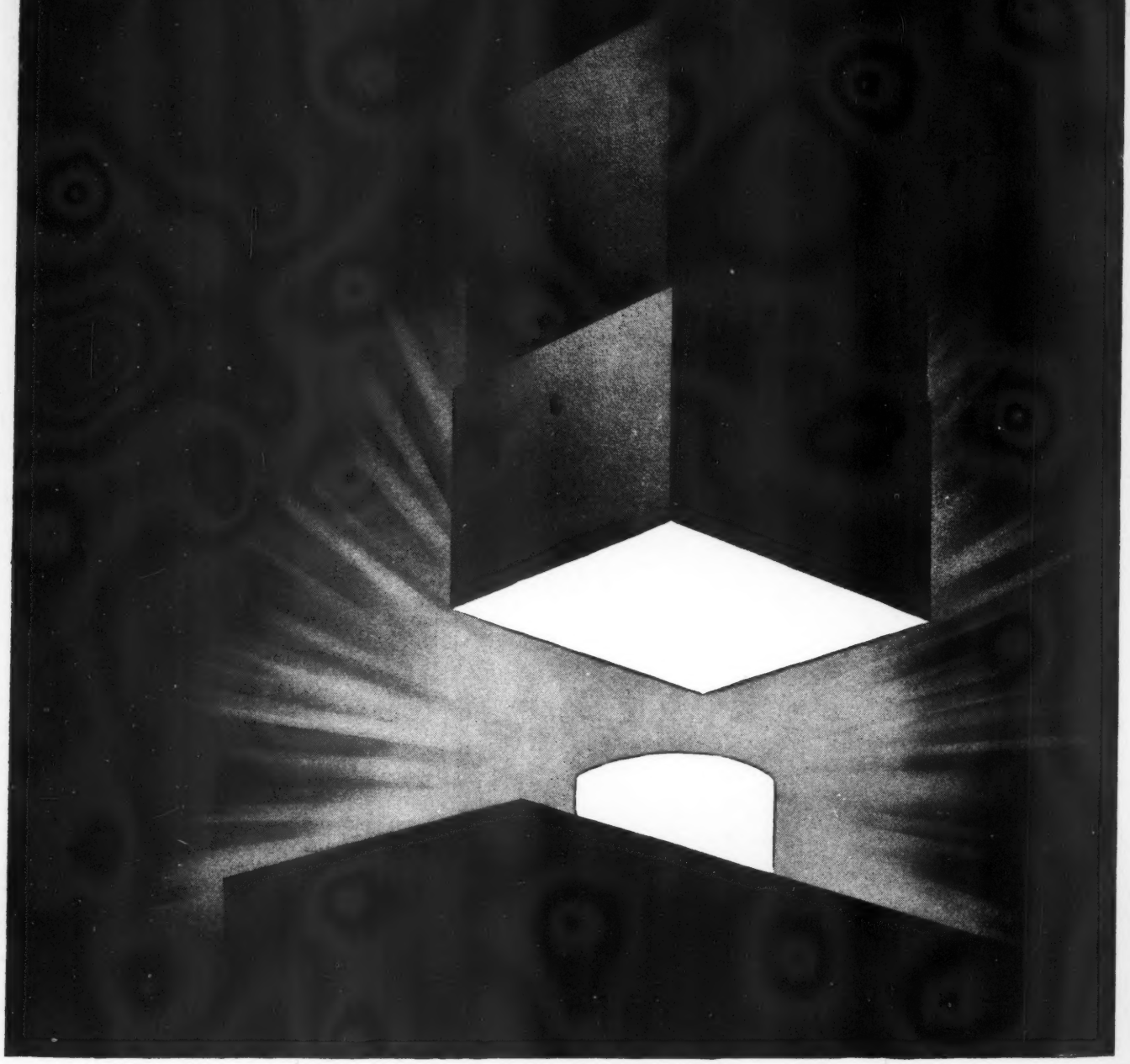

CLIMAX FURNISHES AUTHORITATIVE ENGINEERING DATA ON MOLYBDENUM APPLICATIONS.

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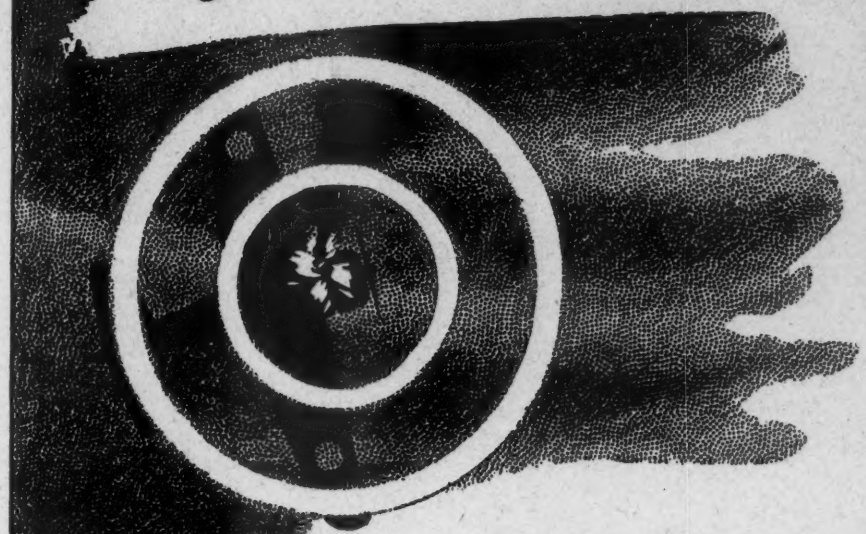
MOLY

CURIOUS FACTS ABOUT LIGHTING



LIKE SHOOTING FISH IN A BARREL . . . There was a time when Jap Zeros could "sit in the sun" and come in with guns blazing—protected from our gunners by blinding sunlight. Not long ago, they had an unpleasant surprise. U. S. Army and Navy gunners now have a *new Westinghouse gunsight lamp* that lets them fire with deadly accuracy—directly into the sun. Formerly, our gunners could aim within only 15 degrees of the sun, leaving a dreaded "blind spot". This has now been removed—and, with it, a lot of Japs.

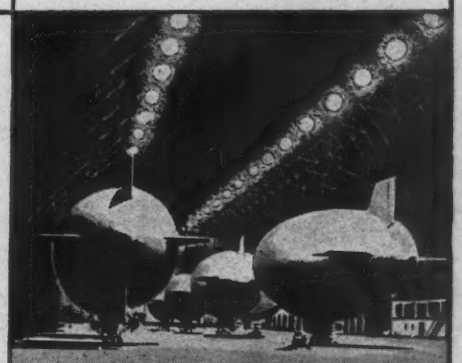
Lamps of 10,000 different types, using from 1/10th to 10,000 watts—incandescent, fluorescent, infrared, ultraviolet lamps, produced at the rate of about 1,000,000 units daily—lamps for seeing, for heating, for fighting disease—*wherever you see the Westinghouse Mazda Trade Mark, you'll find top quality!*

CEILING, 2000 . . . Vital "ceiling" information is provided for American fliers by *alidade* sighting device, which "draws a bead" on a cloud—illuminated by giant Westinghouse searchlight. Height is read directly in hundreds of feet.

HAM AN' . . . New sealed-beam landing lights for army bombers are so powerful that a Westinghouse engineer actually cooked a meal on the surface of an upturned lens. Infrared rays did the trick.

DAVY JONES could find good use for this 1000-watt sea salvage lamp. Inside are loose grains of tungsten which the diver can whirl against the glass—to scour off clouding particles emitted by the filament.

SELF-CONTAINED SUN LAMP, developed by Westinghouse, produces comfortable warmth with infrared, as well as beneficial ultraviolet rays. Mercury vapor, electrodes, reflector, and incandescent filament are sealed in a reflector bulb of special glass, which screws into any lamp socket.



MAXIMUM "SEE-ABILITY" is provided by Westinghouse 3-kilowatt mercury lamps—in blimp hangars, airplane factories, steel mills, etc. These lamps produce 120,000 lumens of light.

Tune in:
JOHN CHARLES THOMAS
Sunday, 2:30 pm, EWT, NBC

Westinghouse
PLANTS IN 25 CITIES OFFICES EVERYWHERE

Tune in: TED MALONE
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COMPLETELY REFRIGERATED SHIPS—"C_2 Reefers" —play an important part in bringing fresh foods to our Armies overseas. Built by Moore Dry Dock Company and equipped by York Corporation, these floating cold storage warehouses, held at a temperature of 15°F., are a major factor in the fighting efficiency of our Armed Forces.

Here is what an official of United Fruit, the operating company, said regarding performance: "Their reliability has been outstanding, particularly under the exacting requirements of the quick turnaround that is one of the major demands made in the refrigerated trade . . . there has been no instance in which any one of them has failed to deliver its cargo at destination in perfect condition—and on time."

Yet York equipment serving in our fleet of refrigerated ships is but a *part* of the total refrigeration tonnage necessary for the maintenance of our Armed Forces. Self-contained refrigerating units on landing craft, in trucks and on trailers bring fresh rations from beachhead to battle zone.

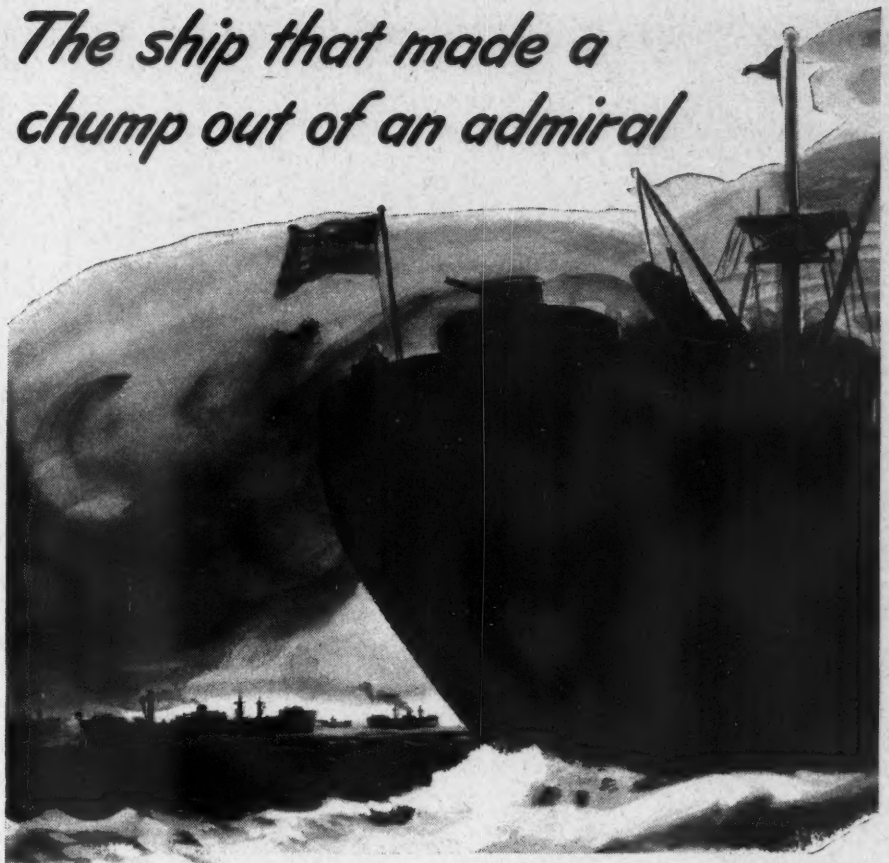
On ship and on shore York equipment is serving with our Armed Forces. In many cases requirements have called for new and superior techniques. Wartime developments will be reflected in materially improved air conditioning and refrigeration for a peacetime world.

York Corporation, York, Penna.

YORK REFRIGERATION AND AIR CONDITIONING

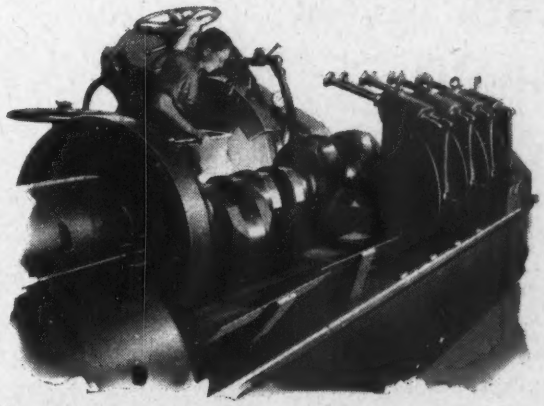
HEADQUARTERS FOR MECHANICAL COOLING SINCE 1885

The ship that made a chump out of an admiral



It took the Liberty ship to make a chump out of Nazi Admiral Doenitz! He told Hitler his U-Boats would starve England out of the war. But he reckoned without our ability to build ships by the hundred and get most of them through safely. We are proud of the part The Carborundum Company played in making that record. For in shipbuilding, as in every other modern industry, "CARBORUNDUM"-made products are helping do the job faster, better and at lower cost.

For instance, grinding wheels by "CARBORUNDUM" precision grind pins and bearings for giant marine crankshafts. They accurately grind and finish engine cylinders, pistons, gears, rods, parts—and miles of ship welds. Abrasives, refractories and "Globar" electric heating elements by "CARBORUNDUM" are all tools vital to production. This wide application offers exceptional opportunities for Engineer-Salesmen. If interested, please write The Carborundum Company, Niagara Falls, New York.



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HELP YOU MAKE THINGS BETTER
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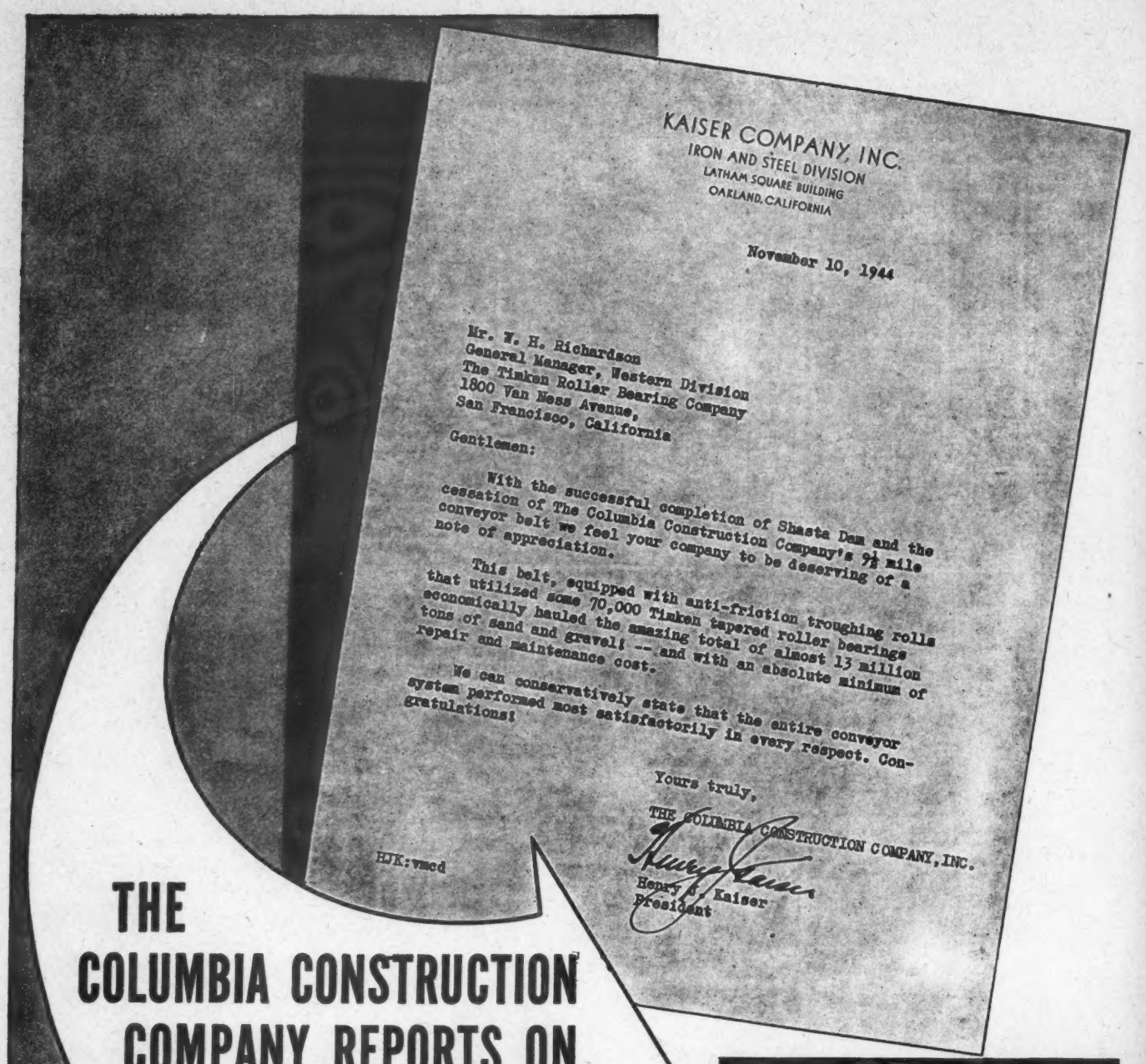
KAISER COMPANY, INC.
IRON AND STEEL DIVISION
LATHAM SQUARE BUILDING
OAKLAND, CALIFORNIA
November 10, 1944
Mr. W. H. Richardson
General Manager, Western Division
The Timken Roller Bearing Company
1800 Van Ness Avenue,
San Francisco, California
Gentlemen:
With the successful completion of Shasta Dam and the cessation of The Columbia Construction Company's 9½ mile conveyor belt we feel your company to be deserving of a note of appreciation.
This belt, equipped with anti-friction troughing rolls that utilized some 70,000 Timken tapered roller bearings economically hauled the amazing total of almost 13 million tons of sand and gravel! -- and with an absolute minimum of repair and maintenance cost.
We can conservatively state that the entire conveyor system performed most satisfactorily in every respect. Congratulations!
Yours truly,
THE COLUMBIA CONSTRUCTION COMPANY, INC.
Henry J. Kaiser
President
HJK:vmcd

THE COLUMBIA CONSTRUCTION COMPANY REPORTS ON TIMKEN BEARINGS AT SHASTA DAM

Timken Bearing Equipped Conveyors manufactured by Chain Belt Company, Milwaukee, Wis.

TIMKEN
TRADE-MARK REG. U. S. PAT. OFF
TAPERED ROLLER BEARINGS

THE TIMKEN ROLLER BEARING COMPANY, CANTON 6, OHIO

HE'S only been out of college three years. He's not much older than you are. At war he is a hero, brave and skilled. And he happens to be something else you may not have thought about.

Already he is the head of a million dollar business. And he is not the boss's nephew either. He came up the hard way . . . Nine grueling months at Randolph Field—sixteen hours a day, all work. Then his wings; and fly, fly, fly, work and learn. And then fight.

Today is his birthday. He's 24, a major, commanding a B-17 Heavy Bombardment Squadron in the Pacific.

Under his command are 12 aircraft . . . total value 4 million dollars, plus astronomic quantities of gasoline, oil, ammunition, spare parts, trucks. And *he* is personally responsible for the smooth efficient running of it all.

And more...he is responsible for the well-being and the very lives of the 400 men in his command.

Esso Aviation Products salute this major, and the hundreds of thousands like him, not only on their flying skill, but on their magnificent job of leadership and administration.

Head of a Multi-million Dollar Business

ESSO LEADERSHIP *in aviation petroleum products stems from two simple facts. First . . . from the time we fueled the Wright brothers' first flight at Kitty Hawk, this has been an air-minded organization. And second . . . we back that air-mindedness with the largest research operations in the business. One out of every four allied combat planes flies on gasoline from the Esso refineries.*

YOU CAN DEPEND ON

COLONIAL BEACON OIL COMPANY

"DEEP IN THE HEART OF TEXAS"—Modern trains of the Burlington-Rock Island R. R. Co. maintain fast service between Houston, Dallas and Fort Worth.

TRAINS OF THE MODERN WORLD

People like to ride on fine trains. It has been proved so in Texas where the stainless steel streamliners "Sam Houston Zephyr" and "Texas Rocket" ply to and fro between Houston, Dallas and Fort Worth. These trains have been so popular that the people of Texas have asked for more trains of the same kind.

They will get them as soon as men and materials for their building can be released from war production. For the railroads realize that future demands for modern, luxurious train transportation will exceed anything known before the war. They need much additional new passenger equipment; they want to provide the best.

And Budd, builder of stainless steel trains, is at work on plans for this future. You will see new trains in increasing numbers, with new refinements, new conveniences. They will give you the comfort of your own living room, even on long journeys. And they will be extra strong and safe, each car a firmly-welded unit of stainless steel, fabricated by Budd's exclusive SHOTWELD* system.

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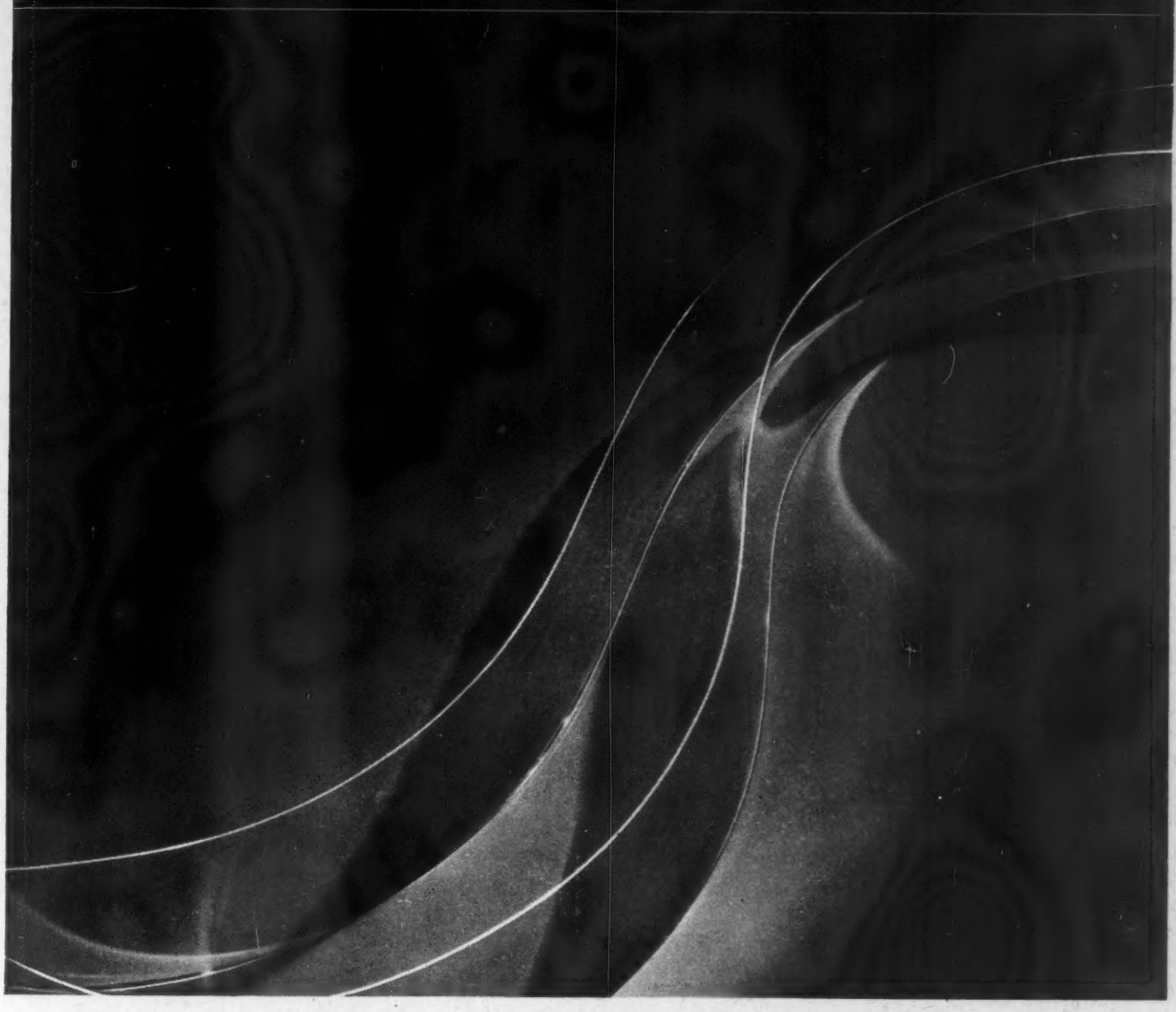
PHILADELPHIA • DETROIT

Originators of ALLSTEEL* *auto bodies, stainless steel lightweight trains and highway truck trailers. Designers and makers of airplane and marine structures. Inventors of the* SHOTWELD* *system of fabricating hi-tensile steel.*

*REG. U. S. PAT. OFF.

Budd

Glass like ribbon candy...



WHAT do you think of this?" said the research physicist, hauling out a long wide flexible ribbon of glass as thin as paper. He shook it and it bent and rattled like rain on a roof.

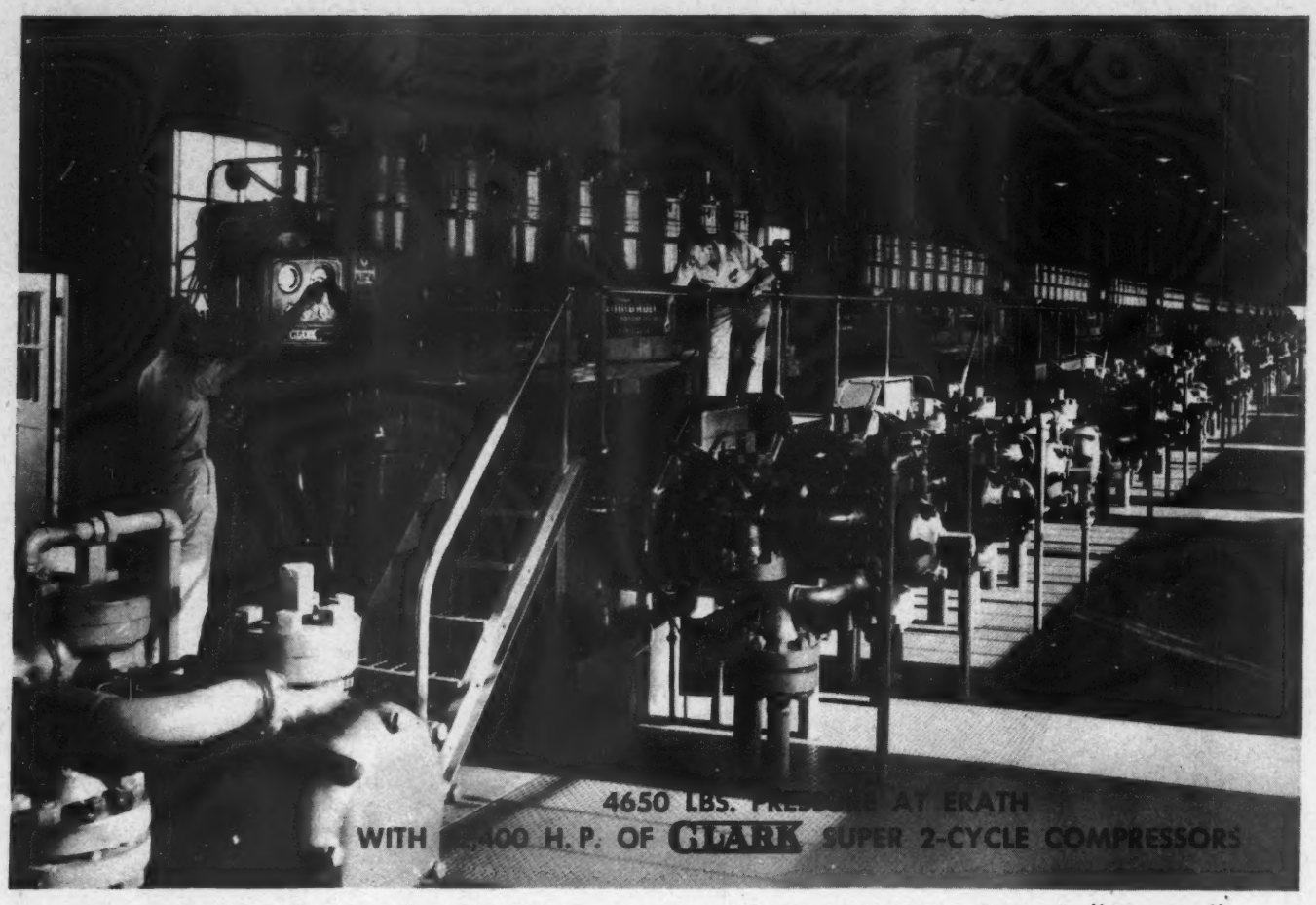
"What's it for?" said the fellow who writes these ads. "Well," said the physicist, "it may have a lot of uses. We haven't had time to explore them all yet. But one we've already found is in wartime radio equipment."

This interesting new type of glass is just one of the many contributions of glass research to the war. For the glass industry has thrown its entire accumulated experience, engineering and research facilities, into the job of putting glass on the fighting and industrial fronts where it can hurt our enemies most.

War and Corning research have put glass in a lot of strange places. For instance, there was a time when almost all piping in chemical plants was alloy of one kind or another. Now chemical people have discovered that glass piping is better for many purposes, and Corning has even developed a method for welding it into continuous lengths.

What about the business *you* choose to follow? Perhaps someday glass can replace metals, speed production, improve products for you. It has for others, and Corning knows how to apply glass to many different problems. Keep it in mind. Corning Glass Works, Corning, N. Y.

CORNING
means
Research in Glass



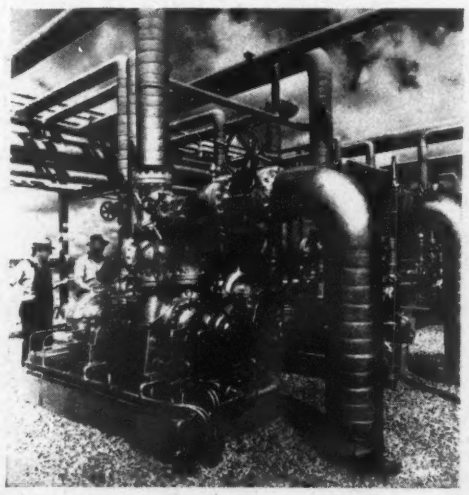
More Gas to the Sand at Higher Pressure with 12,800 H. P. of Clark "Angles"

● The new recycling plant of the Texas Company at Erath, Louisiana, breaks all previous records by returning gas to the formation at 4650 lbs. pressure. The design and manufacture of the 16 Clark "Angle" Compressors for this job called for precision engineering and workmanship of the highest order. Compressor cylinders were designed to meet the exact operating conditions to which they would be subjected. Extremely close tolerances had to be maintained.

The basic economy and dependability of the Clark 2-Cycle "Angle" is demonstrated once more in the most modern type of plant.

INSTALLATION SHOWN AT THE RIGHT *is a battery of Pacific type H.V. Centrifugal pumps delivering peak efficiency in De Tentanizer furnace feed and lean oil service. Type H.V. handles extremely hot or sub zero liquids at low pressure. Speeds up to 3600 R. P. M. Capacities 100 to 3,000 G. P. M., and differential pressures up to 325 P. S. I. It is one of the many types of high precision pumps designed and built by Pacific.*

In pump engineering, Pacific has always anticipated and met the requirements of industry with a long list of "Firsts" in design, and construction.



Two of the Dresser Industries

CLARK BROS. CO., INC.
OLEAN, N. Y.

PACIFIC PUMPS, INC.
HUNTINGTON PARK, CALIF.

THE TECH ENGINEERING NEWS

PROFESSIONAL JOURNAL OF THE UNDERGRADUATES

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Volume XXVI, No. 5

JANUARY 1945

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Courtesy Harold Haliday Curtain

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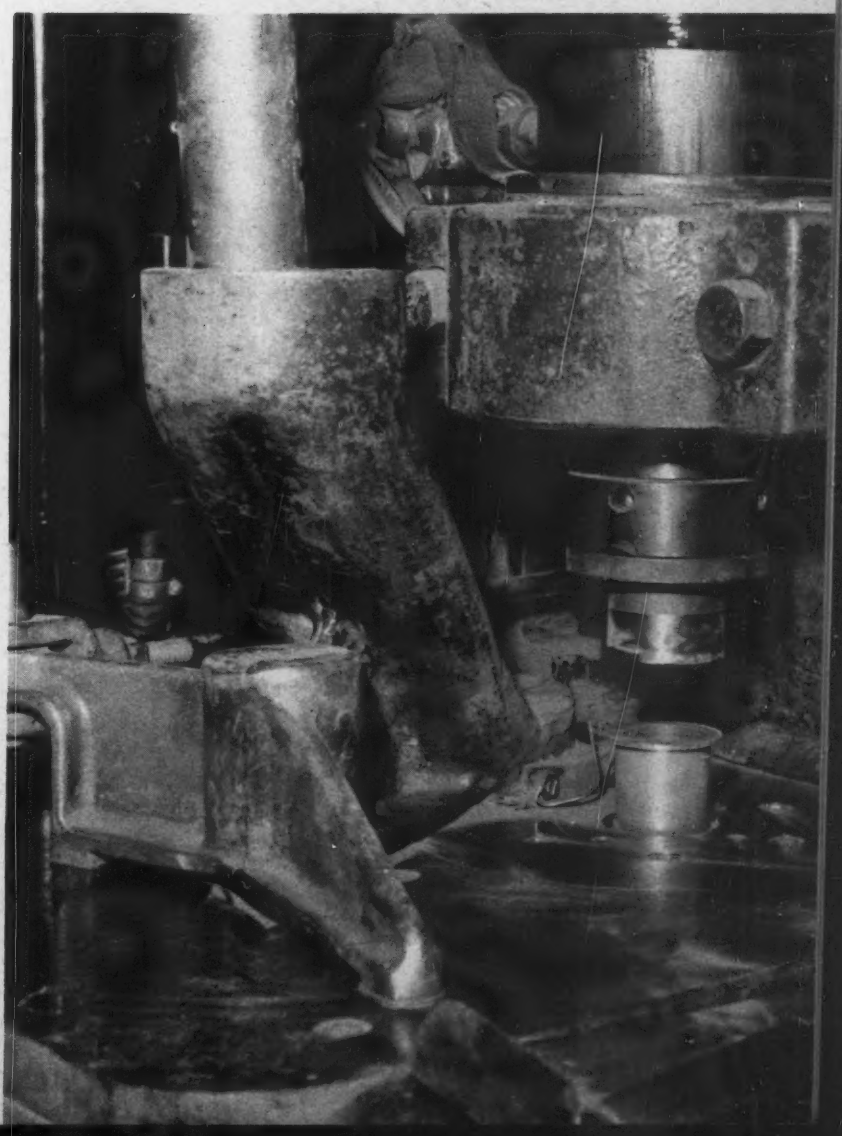


KEEP THAT LINE ROLLING

THIS IS M. I. T.

BUSINESS AND ENGINEERING ADMINISTRATION

By ERWIN H. SCHELL
In Charge of the Department

OF every ten young men who have a flair for science and engineering, there is usually one who has what might be called intellectual claustrophobia, or a fear of enclosed thinking-spaces. While his interests are essentially scientific, and he enjoys gadgetry of one form or another, yet he rather abhors the idea of learning more and more about less and less — of crawling into a specialized hole and pulling the hole in after him. It is particularly fortunate that out of the increasing host of young men who are entering the technical fields, there are these few who have a characteristic yearning for somewhat wider, broader, and deeper applications of their knowledge.

Such young men, if properly trained and stimulated, make about the best executives that industries can find, for their inherent tendency to develop varied interests, coupled with a knack in coördinating these interests in the direction of a common objective, fit them ultimately to become generalists rather than specialists. Yet they can justify a position of leadership because of clear proficiency in the technical arts and sciences.

There once was a time when engineering changes in our manufacturing industries took place much more slowly than at present. Under these circumstances, many of the decisions could be delegated to the technical divisions of the business. Now, with the extraordinary changes which organized research and product development have brought, management itself must be sufficiently proficient in the technical phases of the business to form sound administrative judgments and thereby to keep the enterprise afloat in the swiftly moving stream of progress in which it inevitably finds itself.

It was thirty years ago, in 1914, that the course in Business and Engineering Administration was organized at the Massachusetts Institute of Technology to provide special training for students in this category. The program of study has always been one which has primarily emphasized scientific and engineering combinations. But in place of advanced designs there is introduced a series of fundamental business courses such as production, marketing, finance, accounting, law, labor and statistics.

As a result of four years of this curriculum, young men with a flair for management are given opportunity to range over a broad base of fundamentals which they may sometime have opportunity to coördinate and unify into a manufacturing organization of similar function.

This course at Technology incorporates perhaps as long an interim between initial training and ultimate industrial responsibility as any at the Institute. This is because it takes longer to become a vice-president than to become an engineer. It is true that after this period of development in industry has been achieved, about four out of five of the departmental graduates become major executives. (*Continued on page 148*)

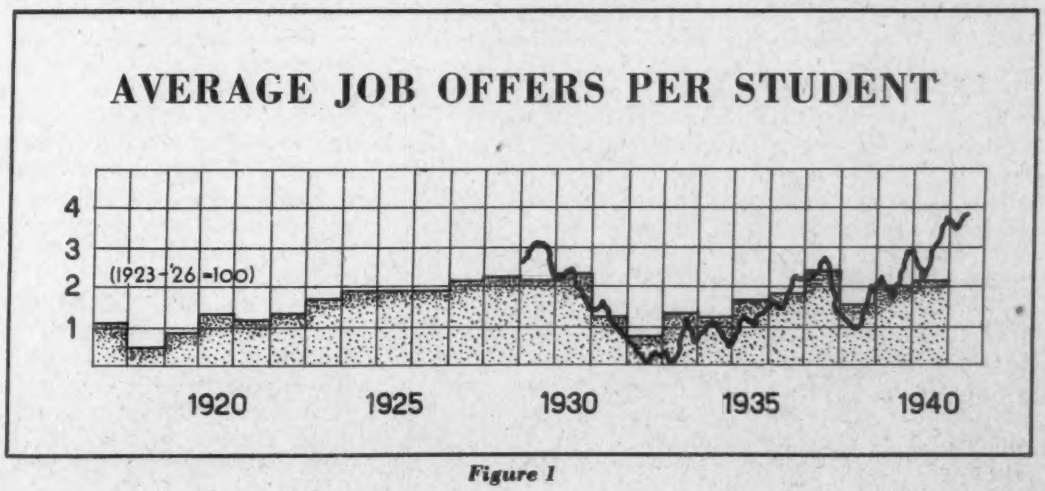


Figure 1

Final assembly at the Republic Aviation Corporation

Courtesy Harold Haliday Costain

AIRCRAFT GUN TURRETS

By HENRY L. LEE, 2–47

HEAVY bombing planes can be defended from swift and heavily armed fighter planes in only two ways. The first is for the bombers to be escorted by their own fighters. Because the required escort is not always available for a mission, or may be engaged with one group of enemy planes while another sneaks in and hits the bombers, the alternate method of protection is necessary. The alternate method is, of course, the arming of the bombers themselves. There is but one major drawback to arming bombers. Guns mean ammunition, armor plating, and gunners, all of which mean added weight. Added weight decreases the size of the bomb load. The enemy must face the same problems as we, and so arms his bombers. The more efficiently we can arm our planes, the more efficient they are as a whole. The buzz bomb of the enemy is a definite attempt to do away with the need for a crew and armament, and thus to use the maximum output of the plane or rocket in its major role — the explosives. Modern planes are powerfully armed — both ours and the enemy's. One of the vital devices in the armament of an airplane is its turrets. Aircraft gun turrets give the pilot mechanical aid in moving heavy guns against the strong slip streams of our fast-flying planes.

The modern power-operated turret is a very efficient affair. It consists of a vertical shaft mounted on a base built into the framework of the bottom of the plane. A hollow shaft fits around the first shaft and is made to rotate by electrically controlled hydraulic pumps. Attached to the top of the rotating shaft are the guns, a seat for the gunner, and surrounding both a large metal ring, called the turret chassis. A large glazed cupola or dome is bolted to this chassis. The guns and aiming devices protrude through slots in the cupola. The guns are also electrically controlled, and an automatic fire interrupter prevents the guns from shooting off parts of their own plane. The guns and gunner's seat are geared to a hydraulic ram and are thus capable of vertical and horizontal movement at the same instant. In almost all cases, the motors and other devices are built right into the turret, and thus comprise a single unit: a single unit that can be replaced in a few minutes by another in case of damage.

The first airplane ever to be armed was a Wright biplane. According to General H. H. Arnold, the armament consisted of a Lewis gun carried in the lap of a passenger. Any conclusions reached were not published. That was the year 1910. In early 1913, the British War Office, because of the rumors of tests being conducted by the French and Germans, decided to experiment with armed aircraft. The Royal Aircraft Factory fitted machine guns to some Henry Farman biplanes. The British Naval authorities, not to be outdone, experimented with a Short pusher float-plane equipped with a semi-automatic Vickers 1½-pounder and a Vickers machine gun. During these tests, ground targets were attacked from heights up to a thousand feet, and some shooting was done using small free balloons as targets. The Coventry Ordnance Company conducted tests to determine the recoil effects of machine guns, using an airplane suspended from the roof of a hangar. In 1914, the Vickers Aircraft Division produced their "Gun Bus" pusher biplane with a Maxim gun in the nose of the nacelle. It was quite successful, and, at the outbreak of the World War, although airplanes were almost universally regarded as observation platforms, the British War Office ordered the large-scale production of a similar model by the Royal Aircraft Factory. The plane was not produced in large numbers until the summer of 1915, by which time more advanced fighters had been developed by the French and the Germans. The development during the rest of the World War continued to be almost entirely in an offensive direction, with little stress being put on defense. Nevertheless, the gun turret had its origin in the first World War. A Sopwith two-seater biplane — the first British tractor machine to have a fixed gun synchronized with and firing through the propeller blades — had a Lewis gun mounted on a metal ring, called a Scarff ring, that pointed to the rear! This was the first serious consideration of the need for defensive armament. A later model of the Scarff ring mounted two guns and was so designed as not to slew around when one gun jammed. The Scarff ring became standard equipment for almost all countries and was not replaced until the increased speed of planes made it imperative that the gunner be given protection from the slip streams.

In 1930 the Bristol Aeroplane Company made the first practical attempt at protecting the gunner from the aforementioned slip streams. A Scarff ring was enclosed within a transparent dome, nicknamed the "birdcage." This innovation established the basic principle of modern turrets. While the enclosure was not power-driven, it was counterbalanced so as to enable the guns to be trained readily and accurately against the pressure acting upon them due to the speed of the aircraft. Bristol next gave the gunner geared hand control over both elevation and traverse of the guns; the gunner moved with the guns and so had the advantage of always sighting through the same panel of the cupola. At about the same time Bristol designed a hand-operated turret with remote control. This was the first layout in which the gunner did not occupy the turret.

Then came attempts to operate the turret by power. The first power-operated turret made its appearance as the nose turret on the Overstroud two-engined medium bomber, both turret and bomber being designed and built by Boulton Paul. The turret was driven by compressed air and mounted a single Lewis gun. Bristol had prepared plans for a power turret for the nose and tail of a big transport-bomber. These plans were realized in the Bristol Bombay troop carrier. The year was 1934.

Bristol used several different systems of electric drive, but finally adopted hydraulics. Of the early electric drives, the most successful consisted of an electric motor driving a disk from which variable-speed and reversing friction drives conveyed motion to the turret, with control by a small joy stick. The mechanism as a whole was not deemed sufficiently smooth in operation and was discarded. Hydraulic systems were then adopted and a certain degree of success was realized.

Still in 1934, Bristol developed a semi-enclosed turret for Army coöperation machines which had relatively low flying speeds. This turret embodied a power pillar with hydraulic operation, giving sensitive control over the movements of the gun, with but a slight increase in size over the earlier hand-operated mountings. During the next year, 1935, the Bristol

Bombay transport-bomber, mentioned above, came out with the first hydraulically operated turret. It was located in the nose of the fuselage and gave the gun a good field of fire forward.

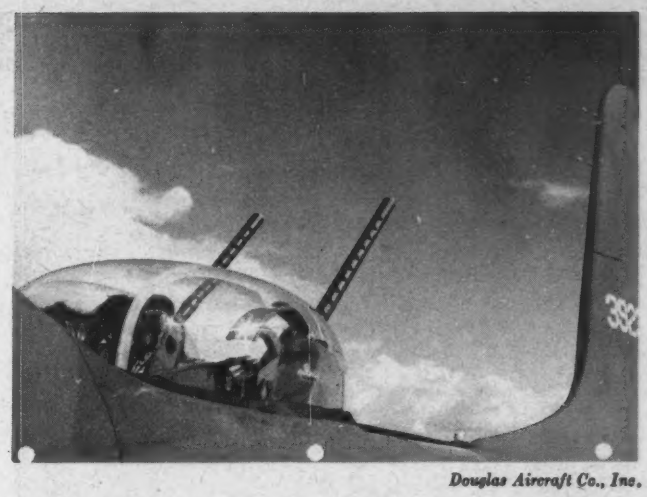
In 1936, there appeared the first of a series of Bristol Blenheim bombers — each with a gun turret amidships. This type of aircraft is notable as having been the first example of the modern all-metal, stressed-skin, cantilever monoplane to go into production for the Royal Air Force — thus introducing a new era of high-performance monoplanes. The latest versions of the Blenheim still have a turret amidships only, but as a bomber it also has a .303-inch Browning gun in the port wing and a "blister" under the nose of the fuselage with a gun firing to the rear. When equipped for long-range work, the Blenheim has the same type of gun in the port wing and the top center turret, but in place of the rearward-firing gun in the blister there are four Brownings firing forward from the nose of the fuselage.

During the early 1930s other aircraft-manufacturing companies besides the aforementioned experimented with power-operated turrets. Vickers fitted its own turrets with twin Browning guns to the nose, top, and tail of the original Wellington bomber. Armstrong used single-gun turrets of another design in the nose and tail of the early Whitley bomber. Neither the Vickers nor the Armstrong turret was entirely satisfactory, and all later versions of the Wellington and Whitley bombers have been equipped with turrets of the Frazer-Nash design, made by the Parnall Aircraft Company. This turret was similar in design to those of Bristol and Boulton-Paul, and constitutes the third of the three makes of turrets now fitted to British military aircraft.

American turrets are applications of the basic principles developed by the early experimenters. American turrets are quite similar to the British turrets, and the methods in which various engineering problems have been solved are the same. One of the most difficult problems is that of turret rotation. The equipment must be light, compact, sensitive, and quick responding. One of the best and most talked about methods of turret rotation is the electro-hydraulic system developed by Boulton-Paul. It consists of an electric motor coupled with a hydraulic pumping unit. The pumping unit consists of two pumps: one, connected in a closed circuit to a hydraulic motor, rotates the turret; another, connected in a similar circuit to a hydraulic ram, elevates the turret.

The cylinder block of the hydraulic pumping unit consists of two banks of five cylinders of $\frac{1}{16}$-inch bore, formed radially about the central vertical bore. The cylinder block is of phosphor bronze, and the piston rods are of case-hardened steel. The outer ends of the piston rods are domed and held centrifugally in engagement with a shallow groove formed in the inner race of a ball-bearing slide ring which surrounds the pistons. Movement of the slide ring gives stroke to the pump in either direction. The whole generator mechanism is contained in a magnesium alloy casing which also incorporates built-in make up on suction valves and adjustable blow-off valves.

The cylinder block is the driven member of the generator and rotates on a fixed steel spindle having two opposed parts for each cylinder bank. Each of the control rings slides in guides in the generator casing and has a range of movement of 0.13 inch to either side of the central position concentric with the cylinder block. In operation, the pistons, in addition to oscillating in their respective cylinders, have also a rotary motion due to a very slight offset of the point of contact between the piston crown and the grooved track in the ball race. This combination of sliding and rotary motion has the effect of equalizing wear and the prevention of line scoring of pistons and cylinders.



Douglas Aircraft Co., Inc.

NEW "STINGERS ADDED", a power turret, housing two .50-caliber machine guns, is the latest addition to the fire power of the Douglas A-20 "Havoc." The "Havoc" now carries nine .50-caliber guns: six in the nose, two shown in the accompanying photo of the turret and one in the belly, firing rearward. This armament puts the A-20 in the fighter-bomber category, because of its speed, maneuverability and general tactical use.

The control slides for the two pumps are connected to a control handle so that movement of the handle to the left or right affects the rotation pump and results in turret rotation in the same direction; movement of the handle backward or forward affects the other pump and results in the elevation or depression of the guns.

Another device coming into use in gun turrets is the amplidyne, a device often used for current control. The amplidyne is a two-in-one generator which uses the same structure twice by means of armature excitation and which gives almost instantaneous response to even the weakest signals. It has been demonstrated that amplidyne responds equally well to several control fields as it does to a single field. The character of the control field windings makes it possible for the amplidyne to be constructed with a multiple control field capable of producing an instantaneous response to a large number of independent signals. The use of the amplidyne with a multiple control field reduces the number of control devices necessary for the desired performance.*

The device that prevents the guns of the turret from shooting away parts of their own plane is the automatic fire-interrupter. Each of the guns, a few feet apart, has a different fire line, and so must be considered independently when its fire is to be interrupted. A device has been developed that controls each gun separately and accurately. Each gun is electrically fired by a separate solenoid with one main switch or button for the gunner to use. By putting a safety isolating switch in the circuit of each gun, one gun can be silenced, while the remaining continue to fire.

The safety device employed on Boulton-Paul turrets consists of a brass drum rotated at the same velocity as the turret. Two spring-loaded brushes are located one above the other on a frame and are held in contact with the drum and are arranged to slide up and down the drum surface as the guns are elevated

* For details of amplidyne's structure, see "The Well-Bred Short Circuit," *The Tech Engineering News*, November, 1943.

(*Continued on page 154*)

POWDER METALLURGY

By C. RICHARD WHELAN, 2–47

Pictures courtesy Chrysler Corporation

Close-up of a briquetting press showing parts of intricate shape being mass produced by the powdered metal technique. Metal powders flow down through the tube, center, are fed into the die, and in a nine-second cycle of the press, the briquette is formed. After sintering for strength and sizing for precision, powdered metal bearings and parts may be impregnated with oil for self-lubrication and will save up to twenty different machining operations.

THE use of metal powders is not a new idea. Powdered gold and silver were known to the ancient Egyptians. The Incas in Ecuador were able to work platinum by cementing grains of platinum with grains of gold and silver. Because of the extremely high melting point of platinum this was the only method by which platinum could be worked.

Metals in the powdered form find many uses today. Aluminum and magnesium powders are widely used in flashlight powder, incendiary bombs, tracer bullets, and flares. Aluminum and bronze powders are extensively used as pigments in paints. Other metal powders are used as catalysts in certain chemical processes.

However, the present definition of powder metallurgy, generally speaking, does not include the above mentioned applications. Powder metallurgy may be defined as the processing of metal powders into metal parts having qualities comparable with cast or forged parts.

The first step in the manufacture of any powdered metal part is the processing of the metal into powder of the desired grain size. There are many ways of getting metal into the powdered form. One widely used method is the process of electrolytic deposition. By controlling the conditions in the electrolysis of a metal salt, the metal can be deposited in the bottom of a tank as a sludge. This sludge is washed, dried, and screened to cleanse and sort the metal particles. This method is used to a great extent in making copper powders because the crystalline structure of the particles formed is advantageous to the conditions present in the making of powdered metal parts. Another important method used to make metal powder is the oxide reduction process. In this process powdered oxide of the desired metal is reduced by heating in an atmosphere of hydrogen or carbon monoxide. A third important process is grinding, hammering, or any kind of mechanical disintegration to form the metal powders. This method is used to make metal powders of the more brittle metals. A fourth and very interesting process for powdering metals is the atomization of the molten metal in a high velocity air jet. There are numerous other methods of obtaining metal powders; the method used depends on the properties of the metal and the type and size of metal particle desired.

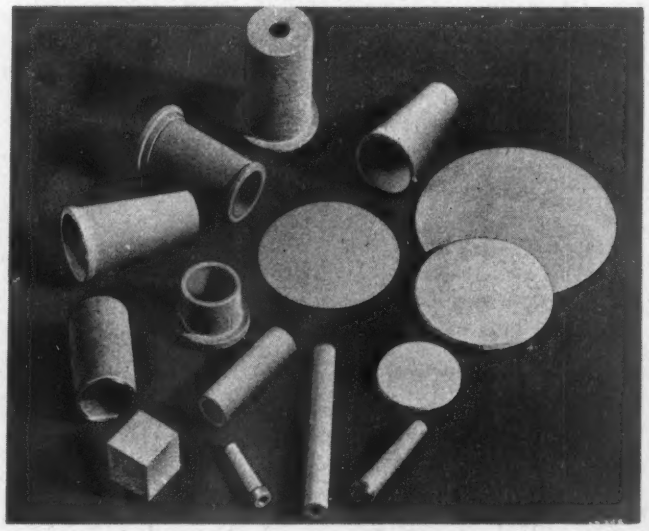
Having obtained the metal in the powdered form it is usually mixed with other metal powders to form a mixture of powdered metals of carefully determined composition and grain size. Thus, the physical properties of the finished powdered metal part can be made to meet many varying conditions.

The mixture of metal powders is then put in a die of the proper shape and size, and subjected to pressures ranging from twenty to sixty tons per square inch, depending on the specifications for strength and porosity. As a result of this the metals are pressed into a shape closely resembling the finished product. The product of this cold pressing or briquetting is called a compact or briquette, and its volume is only about one-third of the volume of the metal powder used. The compact is strong enough to stand up under normal handling until it reaches the heat treatment furnaces.

The next step in the manufacture of powdered metal parts is the heat treatment or sintering process. The compacts are heated in electric furnaces in a neutral or reducing atmosphere to prevent any oxidation of the metal. The proper furnace must be deter-

(*Continued on page 150*)

Still another example of powder metallurgy's rapid rise to the forefront as an accepted and versatile means of manufacturing are the quick acceptance of Oilite Filters. This product in its wide choice of shapes and sizes is used for filtering, venting, mixing, separating, metering, diffusing and flame arresting.



THAT Nth DIMENSION

By ROBERT H. KRAICHNAN, 2–47

HOW would you like to find your way about in a space of 1,000,000,000,000,000,000,000,000,000 dimensions? A bit confusing, you reply? Nevertheless, the physicist who studies the behavior of gases must deal with such astronomically dimensioned spaces as part of his everyday life. In fact, when he comes to simplify and idealize his theories, he finds that he has to consider a space of an infinite number of dimensions. Nor is he alone in his difficulties. In the solution of certain dynamical problems of electromagnetic theory it is necessary at times to work in spaces of a half-a-dozen or even more dimensions.

Despite appearances, these seemingly incomprehensible concepts of the mathematician are not as baffling as they seem. In order to attack these problems of n-dimensional space, let us first see what is meant by "dimension" or "coördinate."

Consider any physical system which is capable of evolution. The system can vary itself, as a rule, in any or all of a number of different directions. For example, a thermodynamic system can vary in pressure, volume, and entropy. The number of ways in which the system can vary is commonly spoken of as the *number of degrees of freedom* of the system.

It should be noted that this number is not a quantity with absolute significance. It depends on the particular properties of the system in which we are interested. In considering our thermodynamic system we may be interested in temperature — volume — pressure relationships and the system would have two degrees of freedom. But in considering the system as an aggregate of individual molecules we find that each molecule has several degrees of freedom, and consequently the number of degrees of freedom of the entire system is quite large.

Let us assume that we have a system with a given number of degrees of freedom. At any given time, we say the system is in a definite observable *state*. Again, this state is arbitrary. For instance, we can specify the thermodynamic state of a system or its electrical state. When the state of a system is completely determined it necessarily follows that all degrees of freedom are removed, because the degrees of freedom describe the ways in which the state of the system can change.

Since the specification of a state involves the elimination of the n degrees of freedom, n quantities must be specified in order to uniquely determine the state. These n quantities are called the *n generalized dimensions*, or coördinates, of the system, and the system as a whole is referred to as n-dimensional. The name dimension arises from the fact that a point in geometric space is a system of three degrees of freedom — the specification of ordinary Cartesian coördinates serves to determine the state.

Of course, it is common knowledge that the coördinates may be chosen to some extent arbitrarily; for example, we may specify the position of a point by either Cartesian or polar coördinates. Or again, the state of motion of a particle may be specified either by its location and momentum components, or by its velocity components and its location. The choice is not altogether arbitrary, however, as can easily be shown.

Consider a system whose state is specified by the determination of n independent coördinates $x_1, x_2, \ldots x_n$. Now make a transformation to another set of coördinates $y_1, y_2, \ldots y_n$ and consider the conditions of the transformation in order to discover restrictions upon the y's. First, it is easily ascertained that, in general, n independent y's are required. This follows from the independence of the x's. It is often possible to verify independence by inspection.

There is, in addition, a second condition which the y's must satisfy individually. That is, each of them must be the integral of an exact differential. The necessary and sufficient condition for this is

$$\frac{\partial A_i}{\partial x_j} = \frac{\partial A_j}{\partial x_i} [i, j = 1, 2 \ldots n]$$

where

$$dy = \sum_{a=1}^{n} A_a dx_a.$$

An illustration of the necessity for this requirement is the case, previously considered, of a moving point in space. Its position cannot be unambiguously specified in terms of its x and y coördinates and the length of the path it has followed, because length of path is not *in general* the integral of an exact differential. Although in this case the condition seems trivial, it is of very great importance in such fields as thermodynamics. For example, the work done in a thermodynamic process is an inexact differential and cannot alone determine the end-state of the system.

We shall now proceed to examine the method in which this concept of dimensionality and coördinates is put to use in solving physical problems. So far, we have attached to the idea of dimension none of the intuitive auxiliary concepts which go along with the idea of the geometric dimensions of ordinary space. The question naturally arises, then, whether or not the scientist depends on such concepts when he applies the idea of n-dimensional "configuration space," as it is called, to the solution of non-geometric problems.

There is no clean-cut answer to this question. In most cases, the use of the hyperdimensional space is merely to provide a matrix upon which results can be inscribed concisely and in an orderly manner, and to suggest, in addition, a language for describing these results. However, it often happens that in the building up of a theory geometric concepts play an important part by way of suggesting identifications and analogies, and thus the picture of a geometrical space becomes more than simply a code for writing down results.

The terminology of geometrical space is so widespread in physics and mathematics that it often appears in situations where its original origin is forgotten. An illustration is the use of vector analysis in physical theory. This is the identification of quantities of the physical theory with the essentially geometrical concept of a vector, or "directed" line. The use of vector analysis is so common that the origin of this identification is often forgotten.

Another example is the designation of certain functions such as the Legendre polynomials as "orthogonal" because they satisfy the relations

$$\int P_n(x)\overline{P}\ (x)dx = N\delta_m^n$$

where N is a normalization factor and δ_m^n is defined as above. This terminology arises from the fact that for

(*Continued on page 154*)

They came out of t

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BY THE PEOPLE . . .

The present war is being fought for many reasons. Of these, the preservation and perpetuation of the four freedoms is perhaps the most vital to the democratic way of life. It is a very necessary part of democracy that it embody the four freedoms, and thus the right to life, liberty and the pursuit of happiness should be accorded to all the people. But it seems to be overlooked — in fact, ignored by some — that the right to life, liberty, and the pursuit of happiness is the right of all the people *in all free states*, and not merely the exclusive right of nationals of the United Nations. The deliberate overlooking of this basic principle of tolerance is in direct opposition to the humanitarian ideal of democracy.

We are concerned, in particular, with the situation in Greece. It seems that there is a war in Greece — has been for some time, in fact — between an army of Greek citizens and the British army. The Greek people did not approve of the government set up in liberated Greece, and, as any free people might be expected to do, demanded a change. But this government was the Greek government-in-exile, which had been maintained in Great Britain during the time Greece was under Nazi domination, and this government was acceptable to those in power in Great Britain. Not only was it acceptable, it was essential that this government be established in Greece if traditional Europe was to be preserved. So the British, apparently, decided that intervention was necessary if the Greek people were to continue to desire a new government, and the intervention took place in the form of the above mentioned war.

Such a situation is deplorable, and, in face of the Atlantic Charter, is downright hypocritical. The actions of Winston Churchill with regard not only to the government in Greece, but also to the government in Italy, Belgium, and Yugoslavia, bear testimony to this, and substantiate the statement we made earlier about preserving traditional Europe. However, that is neither here nor there.

We must retain a sense of fair play, nonetheless, and not blame the British people for the actions of their governmental heads. As in America, there are those in Britain who disagree with the action taken in Greece, and, as in Britain, there are people in America who support it. The British people, as such, do not demand a reactionary foreign policy any more than the American people demand isolationism, and it is important to recognize this fact.

Also, it must be realized that the Greeks are not entirely right, though our personal opinion is that they are nearly so. Their first popular demonstrations began as bloodless ones, and if they had had some organization would have succeeded. But they were not permitted to demonstrate! A violation of one of the four freedoms, ostensibly by order, was the firing upon a group of unarmed Greeks by British soldiers. If, instead of such bloody methods of suppression, arbitration had been attempted, the whole mess could have been avoided.

What did the Dumbarton Oaks conference decide concerning acts of aggression?

The Greeks have right on their side, largely. It would cost the British government little more than pride to admit this and withdraw, leaving the Greeks to themselves. The loss of face entailed here is much, much less than it will be in the world of the immediate future if this civil war is continued.

Furthermore, settlement of the difficulty should be made with the United States and Russia as arbiters, not only in order to observe the conslusions reached at Dumbarton Oaks, but to make the settlement an agreement among the Allies. The Greeks deserve this, at the very least, to insure fair play and eliminate the possibility of British domination.

We question the right of one man, even as the leader of a world power, to intervene in the private affairs of another people. We question his object — the private armies in Greece should be disarmed, granted, as they should everywhere — but the method by which this is being done can only serve to delay its completion and to create among the Greeks a sincere and understandable animosity toward their "liberators." Having been freed from Nazi oppression, by what warped logic does it follow that the Greeks be subjected to British domination? Such action belongs to the world of the past generation. We fail to see how it could possibly be other than detrimental in building the post-war world.

R. B. M.

ALUMNUS OF THE MONTH

DONALD WILLS DOUGLAS

Founder and President of Douglas Aircraft Company, Inc.

Donald W. Douglas was born in Brooklyn, New York, on April 6, 1892, the son of William E. and Dorothy Douglas. He was graduated from the Trinity Chapel School, and, after spending several months at a preparatory school for Annapolis, he passed the United States Naval Academy examinations and entered the Academy in 1909. His interest in airplanes increased to such an extent that after three years at Annapolis, he resigned to enter M. I. T., where he finished the course in mechanical engineering in two years. While at Technology Mr. Douglas was active on the campus and a member of the Delta Psi fraternity.

After graduating from M. I. T. Mr. Douglas went to work as an assistant to Professor Jerome C. Hunsaker, now head of the Department of Aeronautical Engineering at M. I. T. While working in this capacity he helped build what was probably the first efficient American wind tunnel. In 1915 he joined the Connecticut Aircraft Company, working on the first dirigible to be built for the United States Navy.

The year 1916 found him working as chief designer of the Glenn L. Martin Company, working with Eric Springer, Larry Bell, and Edmond Doak, all now key men in the aircraft industry.

After having married Miss Charlotte Ogg in June of that year, Mr. Douglas left the Martin Company in November to become Chief Civilian Aeronautical Engineer for the Aviation Section of the U. S. Army Signal Corps. He was instrumental in designing the Martin bomber which, though it appeared too late for use in World War I, became the building block of the bombing squadrons of the Air Corps.

On his return to the Martin Company after the war, Mr Douglas become vice-president and chief engineer. In 1920 he left Martin to establish the Davis-Douglas Company, financed by David R. Davis, a wealthy sportsman. In 1921 Davis withdrew from the concern and it became the Douglas Aircraft Company. The Company gained fame in 1924 as builders of the four Douglas World Cruisers, two of which completed their globe-encircling voyage.

In 1932, in coöperation with Transcontinental and Western Air, the Douglas Company drew up plans for the DC-1, their first venture in the commercial aircraft field. The plane was tested successfully, breaking numerous records during the test period. The production model of the ship was the DC-2 which was followed by the improved DC-3, now the mainstay of the commercial airlines in the United States.

Douglas gambled on all of these planes. The initial DC-1 cost the Company $307,000 to develop. TWA paid $125,000 for the ship and took options on others at $58,000 each, but later raised this price to $65,000. The first twenty-five ships to TWA netted a loss to Douglas of $266,000, but the plant built an extra twenty-five planes while filling the airline order. Operations were soon out of the red. The seventy-sixth DC ship cleared the loss on the original and the first twenty-five. By June, 1938, some 138 DC-2 planes had been delivered. By then the DC-3 was brought out, the first seven being sold to American Airlines at a net loss of $372,000. But succeeding deliveries soon had the figures on the profit side of the ledger, and the DC-3 was destined to carry 95 per cent of all commercial airline traffic in the United States.

The DC-4, which was the next commercial model made by Douglas, grew from the idea that the airlines could use a super transport — roughly three times the size of the DC–3. It came to life behind huge canvas curtains in a section of the factory and after two years of development became the best known four-motored commercial transport in the world.

Before the giant transport was tested in 1938, around 500,000 hours of engineering time were put in on it. Some 100,000 laboratory hours were consumed in ground and laboratory tests which produced aerodynamic stress that simulated the air path of the DC-4 three times along the world flight of the Douglas World Cruisers. One part of the testing, for the most part unknown to the public, was the "wrecking" of the DC-4. Different parts of the plane were constructed for the sole purpose of subjecting them to strains and wrecking them. This was to prove by means of scientific destruction the blueprints of the engineers.

Forty DC-4's were ordered by domestic airlines for delivery in 1942. After Pearl Harbor, the need for military transport planes became urgent, so the Army took over the airlines' orders, adding their own requisitions at the same time. The military version of the ship, the C–54, has many added improvements, making it one of the most valuable cargo carriers possessed by the United Nations.

Mr. Douglas has received recognition of his outstanding work in aviation. He received the Collier Trophy for the most outstanding achievement in aviation in 1935, and in 1940 he was awarded the Daniel Guggenheim Medal for outstanding contributions to the design and construction of military and transport airplanes during 1939.

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AMERICAN SOCIETY OF MECHANICAL ENGINEERS

The first event of the A. S. M. E. winter schedule was a lecture entitled "Engineers with MacArthur," presented by Dean George R. Harrison. Having spent the summer working on technical developments with General MacArthur in the South Pacific, Dean Harrison was well posted on this type of research and gave an extremely interesting account of his work and the problems encountered.

In early December, the members of the Student Branch attended a field trip to the new Mystic Power Plant of the Boston Edison Company. Since this plant contains all the latest developments in power engineering and is operating under one of the highest efficiencies in the country, the trip proved to be both interesting and practical. More visits such as this are planned in the near future, and all members are urged to attend.

The New England Regional Meeting of the student branches from all the surrounding colleges will take place in January here at Tech. The usual essay contest will be held as well as other events of interest to engineering students. The main feature of this meeting will be a lecture on "Jet Propulsion" to be presented by Professor Keenan.

THIS IS M. I. T. — BUSINESS AND ENGINEERING ADMINISTRATION

(*Continued from page 139*)

Studies of the graduates indicate that many of these executives are in the smaller or medium-size companies where managerial opportunities offer wider variety than would be the case in the larger and more highly specialized organizations.

The trend of activity of graduates from this course swings quite rapidly after the first few years from apprenticeship training into technical work and, to some extent, into the assuming of minor executive responsibilities. As the years pass, more and more students turn from technical activities into mid-zone executive tasks, later advancing to become major executives with other executives reporting to them and having responsibilities for broad company policies. Students entering this course have the opportunity to undertake their technical or engineering subjects either in the physical sciences or in the chemical sciences. As a result, they are in position to obtain a special engineer's license in any State in the Union, having in addition their managerial training with a special emphasis upon the problems of industrial manufacturing.

The method of presenting business subjects is along somewhat different lines than in those fields where more exact calculations can be made. Management problems usually contain factors which are in a constant state of change. More than this, there are frequently present elements which cannot be measured precisely. For example, in the determination of a suitable location for a manufacturing establishment, three different cities may be considered. Thus far, there has been no exact way of measuring the precise attitude of executives toward the prospect of living in each of these locations. Yet this may, under certain conditions, be an important element in the final decision. Finally, it is almost never true that all the data necessary for conclusions can be obtained, due to competitive conditions. It is not always possible to ask the competitor just what his plans may be, and yet these very plans may vitally affect company decisions. The task, therefore, in the teaching of business administration is to help the student to apply the scientific method insofar as possible, and even more important to become familiar with the various intellectual approaches which are necessary in dealing with different kinds of business problems. For example, an executive immersed in a sales problem does a quite different type of thinking than one who is engrossed in a purchasing problem. As in golf, he uses a different club for different shots. When these techniques are harmonized and correlated with methods of scientific analysis learned when studying the more exact sciences, the resulting product is a type of thought which capitalizes both upon analytical ability and business judgment.

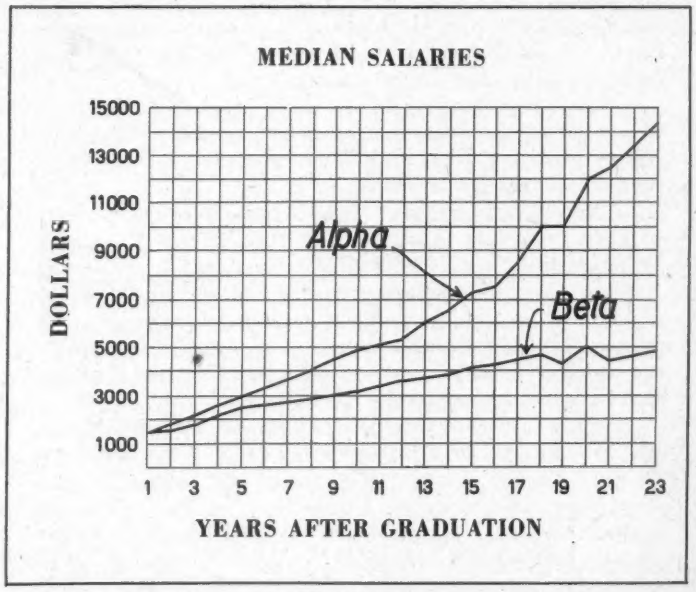

Figure 2

Thus far, little has been said about the objectives of such a curriculum. It is the profound conviction of the members of the faculty who present this program of study, that the greatest social contribution the businessman can make is the continuity of his enterprise. When the manufacturing establishment is managed progressively and competently, it proceeds with stability and assurance of employment. All the parties at interest, such as the stockholders, the executives, the community, the employees, the vendors, and the markets, are benefited. The problem of the business administrator is so to conduct his enterprise that the interests of all these parties are simultaneously safeguarded to the end that the greatest benefit to all is obtained.

Problems of this nature are given particular consideration in the senior year, where a special course

(*Continued on page 150*)

Research gives TELEVISION new horizons

● TELEVISION RAYS—like human sight—do not "bend" far beyond the curvature of the earth. They travel in a straight line to the horizon—and from the horizon off into space. In preparing television as a service to the public, research has sought ways to extend television's program service by radio relaying from city to city.

A solution to this problem has been perfected by RCA engineers: the radio relay station—capable of picking up and automatically "bouncing" television images from station to station. With such relays supplementing a coaxial cable, entertainment, sports and news events could be witnessed simultaneously by Americans from coast to coast.

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THIS IS M. I. T. — BUSINESS AND ENGINEERING ADMINISTRATION

(*Continued from page 148*)

dealing with broader questions of industrial policy and operation is required of all students.

Except in periods of extreme depression, the demand for students from this course has always exceeded the supply available, as evidenced by the accompanying chart where it is evident that it is normal to expect an average of two offers of positions per student, this demand fluctuating rather strikingly in relation to the curve of physical production. The Massachusetts Institute of Technology finds itself most advantageously situated in presenting this program inasmuch as there are eight thousand manufacturing establishments in Massachusetts alone. The department has in the neighborhood of two hundred coöperating establishments which open their doors to students for plant visits and other investigation. In addition, it is the requirement of the program that at least one summer be spent in industrial activities, so that a practical background of operating experience is gained. Thus far, about sixteen hundred students have graduated from the department, which maintains close relationships with its alumni. Every five years, statistics are obtained from which important decisions as to departmental policy may be established. The last such study, made in 1940, divided departmental alumni into those who were in the upper two-fifths of the class salary-wise (Alpha), and those who were in the middle two-fifths (Beta). The accompanying Figure 2 reflects the median incomes of these two groups. In general, it has been found that the students in the upper group are more largely in the medium or smaller industries.

The future for such graduates appears unusually bright. As the war draws to a close and the nation's industries return to ways of peace, problems of good management will once more come to the fore. Whereas during the war, patriotism has required production at any cost, after the war, costs will inevitably reassume their dominant position, and managerial effectiveness once more will become a problem of economy as well as of output.

But of greater importance than this is the great responsibility which business administrators of the future will bear to the public in the provision of sufficient employment and in the assurance of good working conditions and adequate remuneration. Whatever the future may hold, of one thing we may be sure. Industry will go on, for without it the people perish. And there can be no industry without management.

POWDER METALLURGY

(*Continued from page 142*)

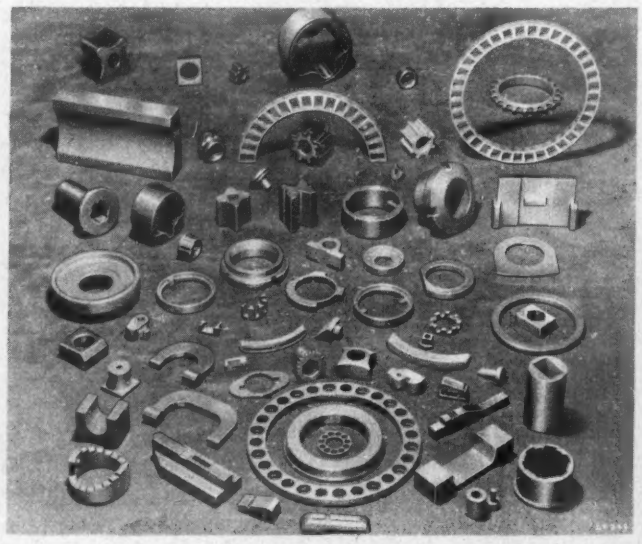
mined for each different batch of metal compacts and this temperature is carefully controlled in the heat treating process. This temperature is usually about two-thirds of the melting point of the lowest melting point metal used. The exact nature of the physical change taking place in the compact during the sintering process is not known, but it can best be described as a welding or bonding of the metal particles in the compact.

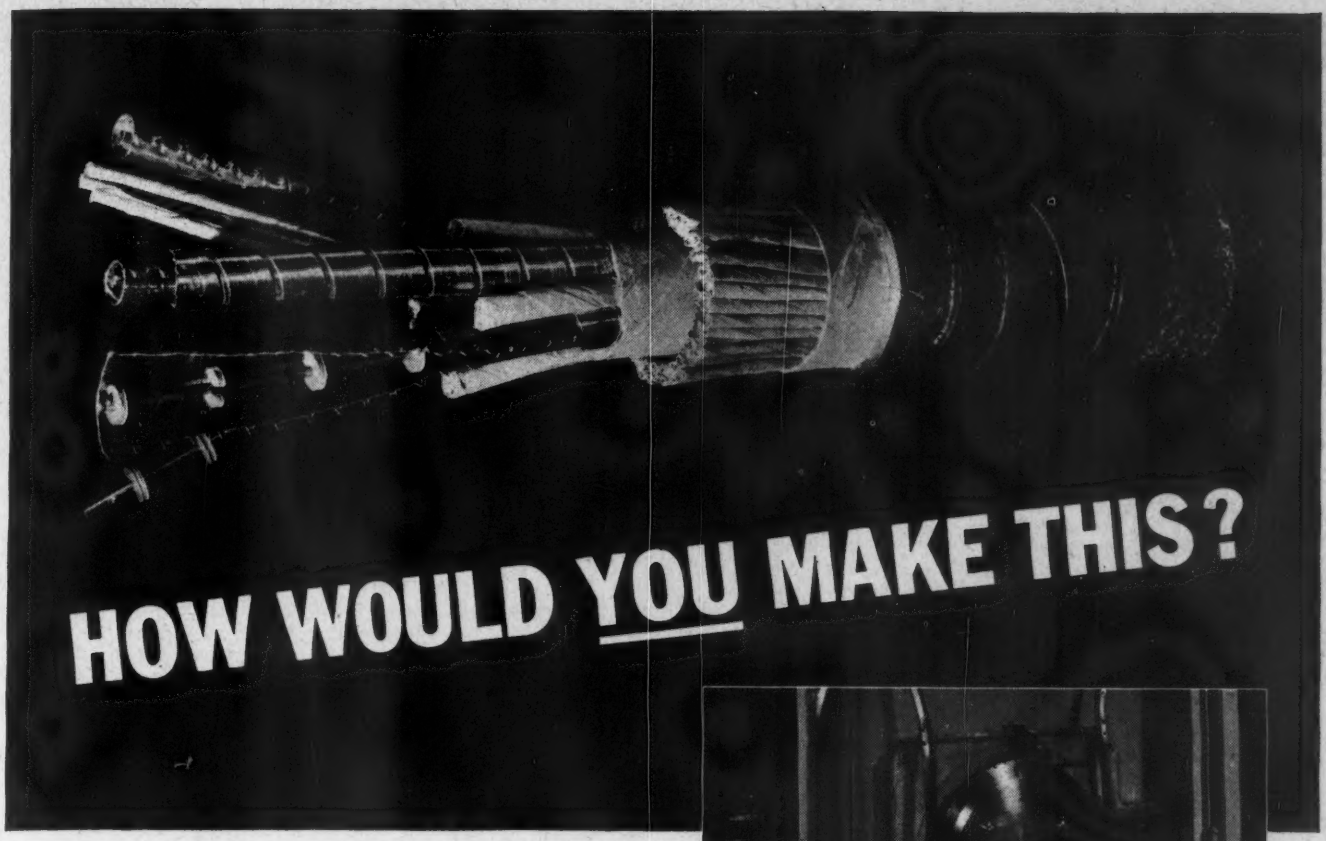
After the sintering process the powdered metal parts are put through a sizing press operation which corrects any changes in the dimensions of the part due to the sintering of the metal. The result of this operation is a strong, porous metal structure which, in most cases, requires no additional machining.

One of the most widely used applications of powder metallurgy is in the manufacture of self-lubricating bronze bearings. In the making of these bearings a mixture of about ninety per cent copper powder and about ten per cent tin powder is used. In some cases a small amount of powdered graphite is added to act as a die lubricant. The usual tolerances for bearings are

(*Continued on page 152*)

A cross-section of machine parts made up to 200 times faster than standard methods from a wide variety of metal powders.





ABOVE is a cutaway section of a coaxial cable which may be used to provide telephone, television or sound program circuits. Its complexity—it can furnish as many as 480 telephone circuits over each pair of coaxials—offered a real challenge to the ingenuity of the Western Electric engineers who had to plan its production and design the equipment to manufacture it in large quantities.

Evidence of their ability to meet the challenge is shown in the intricate machines pictured here. These are but two of many designed by Western Electric engineers to manufacture coaxial cable,

With over 1,000 route-miles of coaxial cable now in operation or being laid, tentative plans call for a coast-to-coast network by 1950—all made possible by the ability of Western Electric engineers to lick the problems of manufacturing the complex coaxial cable quickly and in quantity.

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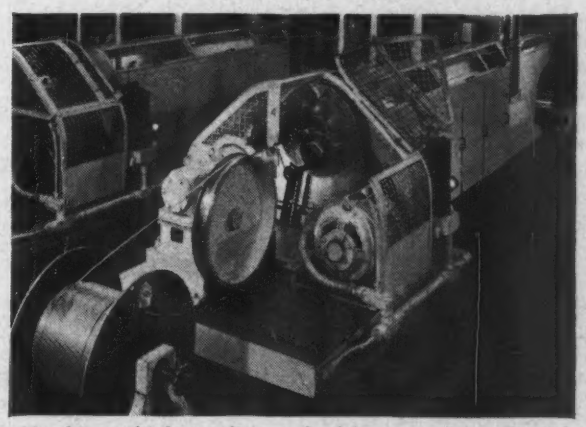
Spacing and fastening insulating discs on the center wire of the coaxial.



Machine which applies a double wrapping of steel tape to the coaxial unit.

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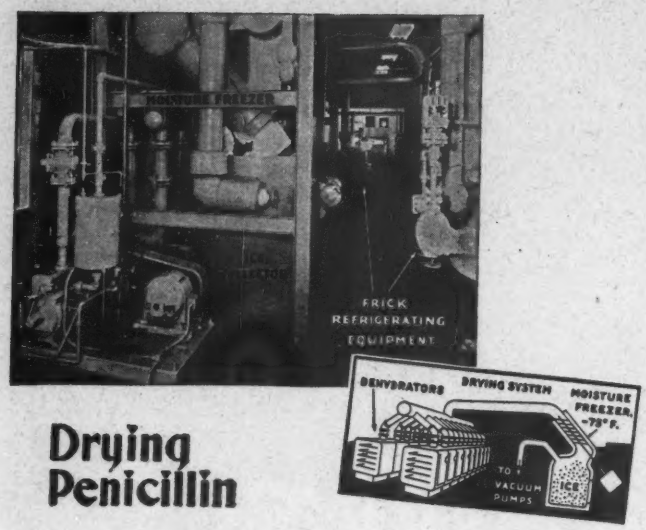

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POWDER METALLURGY

(*Continued from page 150*)

0.0005 inches for bores and outside diameter, and 0.005 inches for length. Powdered metal bearings can be made to meet these tolerances without any machining. Even small tolerances can be met but only by special operations. The sizing press operation gives the bearing a smooth, mirror-like surface, assuring minimum friction. The bearings are impregnated with liquid lubricant of any desired viscosity and the volume of oil contained in the bearing may be as high as thirty-five per cent of the total volume of the bearing. The bearing is uniformly porous and the pores are intercommunicating. Capillary attraction assures the presence of uniform oil distribution throughout the bearing and on the bearing surface. The pores on the metal surface cannot be seen by the naked eye, but if the bearing is heated or put under pressure the oil is seen to seep out through the pores onto the surface of the bearing. Any tendency toward excess friction between the bearing and the shaft while in operation will cause excess heat which, in turn, will cause more oil to move to the bearing surface, thus lessening the friction. It is for this reason that powdered metal bearings are called self-lubricating.

The porosity of a bearing, or any other powdered metal part, depends largely on the pressure used in briquetting the powdered metals. In general, a low pressure will give a bearing of high porosity which gives best service for light loads at high speeds; a high pressure will produce a bearing of lower porosity which is capable of withstanding heavy loads at low speeds. Some manufacturers warn against using powdered metal bearings where shock or impact loads are encountered. Chrysler engineers point out that the porous bearing filled with oil acts as a hydraulic cushion against shocks and sudden impulses. Furthermore, service reports indicate that when powdered metal bearings are subject to severe conditions they perform very well.

The use of self-lubricating bearings is not limited to machines which wear out before the oil contained by the bearing is exhausted. There are numerous ways of overcoming this limitation. For instance, oil reservoirs can be made in the side of the bearing housing. These consist merely of a small cavity stuffed with felt or some other porous substance which is in contact with the outside surface of the bearing. The felt is impregnated with oil, and serves as a wick to replenish the oil supply in the bearing.

Due to the smooth surface and small tolerances of these bearings they can be installed with smaller clearances than are possible with cast and machined bearings. The installation process is very simple, requiring no special equipment or skilled workmen. An accurately dimensioned plug is inserted into the bearing and the bearing is then pressed into the bearing housing. The plug prevents any change in the bore of the bearing, and when removed leaves the inner surface of the bearing undistorted.

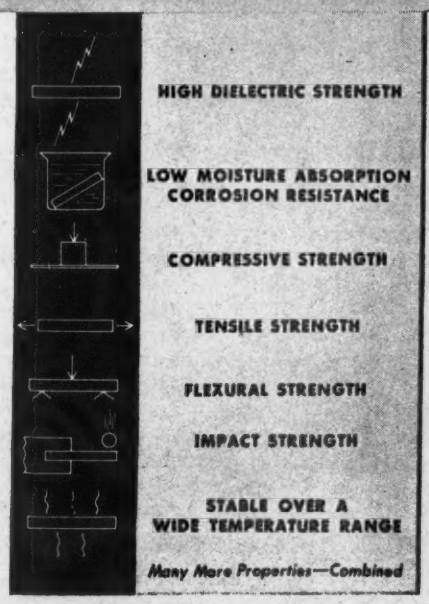
There are certain advantages of parts made by powder metallurgy that make this type of metal ideal for the manufacture of bearings. As mentioned above bearings made by powder metallurgy are self-lubricating, require no machining, and are easily installed. Powdered metal bearings are replacing cast bronze bearings and in many applications give even better service than ball and roller bearings. This better service is given to the consumer at a great saving in metal, working time, and in most cases reduced cost.

It is not hard to imagine that during the wartime emergency, production of powdered metal bearings and other parts has been greatly increased. The application of self-lubricating bearings to armaments production has been staggering; a four-engine bomber alone uses four thousand of these bearings. In the making of cast parts a high percentage of metal is turned into scrap. Gates and risers must be remelted before the metal can be used again. Due to the nature of the casting process many parts are rejected as scrap because of blow-holes, cracks, and other defects. However, in making powdered metal parts practically no metal is wasted in forming the compact, and due to the high purity and accurate composition of the metal involved, the number of defective parts is at a minimum. This has resulted in tremendous savings of vital copper and tin. The great saving in the number of man-hours necessary for production has also stimulated the use of powder metallurgy for many small and intricate parts. A cast part which might require several hours of machining can be formed by briquetting in a matter of seconds. Also, a war plant working against time can usually get an order of powdered metal parts in less time than it would take to get the cast and machined parts.

The shortage of copper caused by the war stimulated development of the use of iron-copper and pure iron powders in the manufacture of bearings and other parts. Pure iron and iron-copper alloy porous metal bearings are now manufactured and sold commercially. These iron powdered metal bearings have several distinct advantages over similar bronze bear-

(*Continued on page 160*)

Franklin's $64 Question Gave Electricity a Job



LIGHTNING streaked through ages, feared but unchallenged. Then to Benjamin Franklin it flashed the answer to a question that unlocked the future of electricity.

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AIRCRAFT GUN TURRETS

(*Continued from page 141*)

and depressed. Firing circuits for the left-hand and right-hand guns are fed by the upper and lower sliding brushes respectively, a fixed brush in permanent contact with the brass drum forming the other connection. On the upper half of the drum, shadow patterns that correspond to obstructed areas are cut out and filled in with an insulating material. These "shadow patterns" are determined by actual experiment so that no matter how complicated the aircraft, it can be adequately protected from its own guns with a minimum loss of field of fire.

Other devices included in turret construction are auxiliary services such as oxygen, intercommunication, and outlets for the gunner's clothing-heater plug. Many modern tail turrets are fed ammunition down a long steel track from the middle of the plane, thus reducing the weight of the tail and permitting an increased ammunition capacity. Cartridges are held together by small metal links, rendering the resulting belt quite flexible. The cartridges and links — after fire — are jetisoned into a flexible tube where they are dropped from the plane.

The modern aircraft gun turret is a compact, light and efficient device that gives the gunner mechanical aid in aiming his guns and gives him protection from the force of fast-moving slip streams.

THAT Nth DIMENSION

(*Continued from page 143*)

successive values of the argument x, the functions may be considered as components of vectors in a space of an infinite number of dimensions. Hence the vanishing of the integral corresponds to the vanishing of the scalar product of the vectors, the usual condition for perpendicularity or orthogonality.

For the present we may sum up by saying that the concept of many-dimensioned space as used in physics provides a method for efficient handling and classification of facts, offers a sort of visualization, and provides a concise notation.

Let us now turn to a discussion of some specific cases in which the method is applied. We start with an example drawn from classical mechanics:

Consider a dynamical system in space consisting of an aggregate of n particles. The system then has a total of $9n$ degrees of freedom corresponding to the components of displacement vector, velocity vector, and spin momentum vector for each particle. Thus we must specify values of $9n$ generalized coördinates in order to fix the state. Adopting the Lagrangian viewpoint we will take as these coördinates the vector components mentioned above. For simplicity we shall consider only conservative systems consisting of particles without spin. The curvilinear space coördinates are the q_i and the velocity components $\dot{q}_i$. Lagrange's equations give

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{q}_i}\right) - \frac{\partial T}{\partial q_i} = -\frac{\partial V}{\partial q_i} \quad [i = 1, 2, \dots 3n]$$

where T is the kinetic energy function expressed in terms of the q_i and the $\dot{q}_i$, and V is the potential energy. Dots indicate time derivatives. Solution of these equations with appropriate boundary conditions and constraints introduced describes the motion of the particles as a function of time.

Here we have a typical example of the use of generalized coördinates in n-dimensional space. It will be noted that the designation of the q's and $\dot{q}$'s as "coördinates" implies, in this case, no relation to geometrical space. It merely provides a terminology and a convenient mathematical notation.

In other cases, however, the concept of the coördinates as fixing a point in "configuration space" does have some value in itself. For example, it was discovered that Lagrange's equations as given above are applicable to situations where the ordinary meaning of the energy function in terms of elementary quantities is lost.

As an illustration, consider a simple electric circuit with capacitance C and self-inductance L. If at time t the charge and current are q and $i(=\dot{q})$, respectively, the total energy of the system is given by

$$U = \tfrac{1}{2} L\dot{q}^2 + \tfrac{1}{2}\frac{q^2}{C}.$$

To apply Lagrange's equations, we take the velocity-dependent part, $\frac{1}{2} L\dot{q}^2$, as kinetic energy, and the remainder as potential energy, where q and $\dot{q}$ are chosen as generalized coördinates. We then obtain directly the differential equation describing the behavior of the system:

$$L\frac{d^2q}{dt^2} + \frac{q}{C} = e$$

Similar applications of the principle may be made to other problems in electricity and thermodynamics.

In order to suggest this extension of the equations of motion of particles in real space to the behavior of an electrical system in configuration space, it is necessary to transfer some of the properties of the real space to our hypothetical space. Of course, this identification is not theoretically required and Lagrange's method can be justified by other means. In other words, the intuitive association of geometrical ideas with configuration space, while not rigorously dictated, is helpful in suggesting significant quantities and operations.

Next consider the value of generalized coördinates as applied to the science of statistical mechanics. We consider any physical system; for convenience, a gas. The method in general outline is applicable to a number of situations.

As in a previous case, if there are m particles without spin momentum, the number of degrees of freedom is $6m$ and we require $n = 6m$ generalized coördinates and momenta, the q_i and p_i. The change in the state of the system is described by the motion of a point through the "phase space" constructed about the q_i and p_i in Cartesian coördinates.

This phase space has many of the properties of ordinary geometric space. For example there exists the "volume element"

$$d\phi = dq_i \cdots dq_n dp_i \cdots dp_n$$

which remains unchanged for any translation and rotation of coördinates.

Following the method of Gibbs, the statistical properties are treated in the following manner: We consider an ensemble of N similar phase spaces, each containing its own representative moving point. We then take any one of these spaces and in it plot simul-

taneously the positions of each of the N representative points. The statistical probability of a state is related to the density of the cluster of points about the region corresponding to the state. That is,

$$P = A\frac{dN}{d\phi}$$

where the normalization factor A is determined by

$$\int P d\phi = 1.$$

From this fact the ensemble of phase spaces may be tied up with thermodynamic systems. It is in this way that we are confronted with the 1,000,000,000,000,000,000,000,000 dimensions mentioned at the beginning of this article.

In the development of the theory, an important part is played by theorems and concepts which have a direct analogue to, and which are suggested by, situations in ordinary space. For example, the famous theorem of Liouville states that

$$\frac{\partial P}{\partial t} + \sum_{i=1}^{n} \frac{\partial P}{\partial q_i}\frac{dq_i}{dt} + \sum_{i=1}^{n} \frac{\partial P}{\partial p_i}\frac{dp_i}{dt} = 0$$

As it stands this equation does not seem to have any special significance; but rewritten in the form

$$\frac{\partial p}{\partial t} + \nabla p \cdot \vee = 0,$$

where ∇ refers to both the q's and p's, it is precisely the law of flow obeyed by an incompressible fluid of density p in ordinary three-dimensional space. Hence we are allowed the interpretation of Liouville's theorem as requiring the representative points to travel through phase space like the particles of an incompressible fluid.

This is a typical illustration of the applicability of the concept of hyperdimensional space. We are provided not only with a concise notation, but also with a sort of intuitive guide to the development of a theory.

To round out the picture, let us take up an example where the geometric concepts of space make up the entire structure of a theory, namely, the relativity theory. Here we find a complete identification of the properties of matter and energy with the geometrical properties of a four-dimensional curved space. For example, the Newtonian gravitational potential becomes closely identified with a factor used in measuring "distance" between two points in the space. The gravitational force itself becomes

(*Continued on page 157*)

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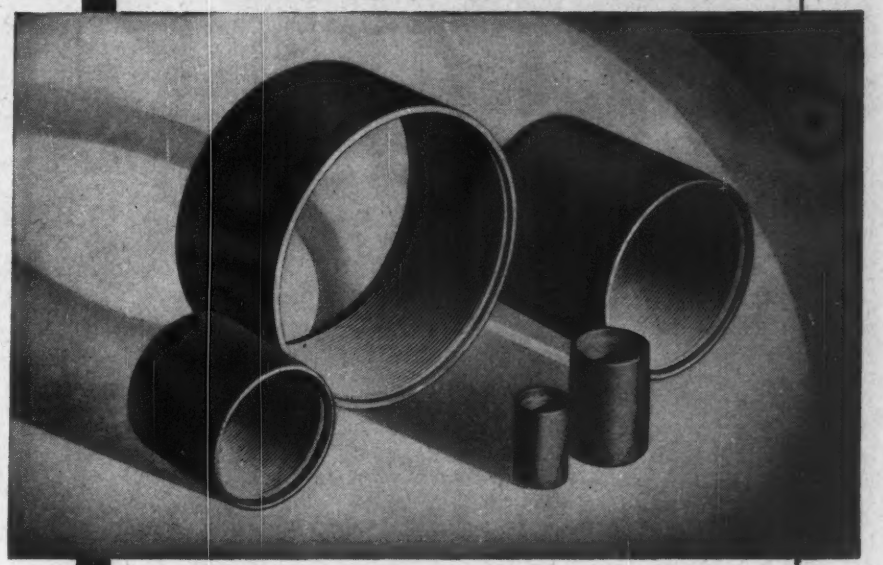

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THAT Nth DIMENSION

(*Continued from page 155*)

identified with the components of the system in curvilinear coördinates. The mechanical properties of matter are given by a complicated expression involving the first and second order components of curvature. Electromagnetic phenomena may be related, with some degree of success, to a geometric quantity derived from the notion of parallel directions.

In conclusion, it should be mentioned that the concept of many dimensional configuration space has found very wide application in the field of modern atomic physics. Although the complexity of the subject precludes our investigating it properly, we may give in a qualitative manner some illustration of the nature of the applications.

The method is, in general outline, quite similar in some respects to examples we have already considered. That is, components of the position and velocity vectors of the particles considered are taken as generalized coördinates. Several additional quantities are considered, however, one of the most important of these being the "spin coördinate" associated with the spin of an electron.

In working some of the problems in this field we come upon a very interesting situation. The points of configuration space do not always form a continuum! That is, only certain discrete values of some of the coördinates are permitted. This leads to the bewildering concept of a geometrical space with only a finite number of points.

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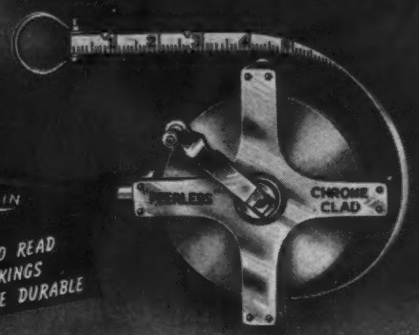

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POWDER METALLURGY

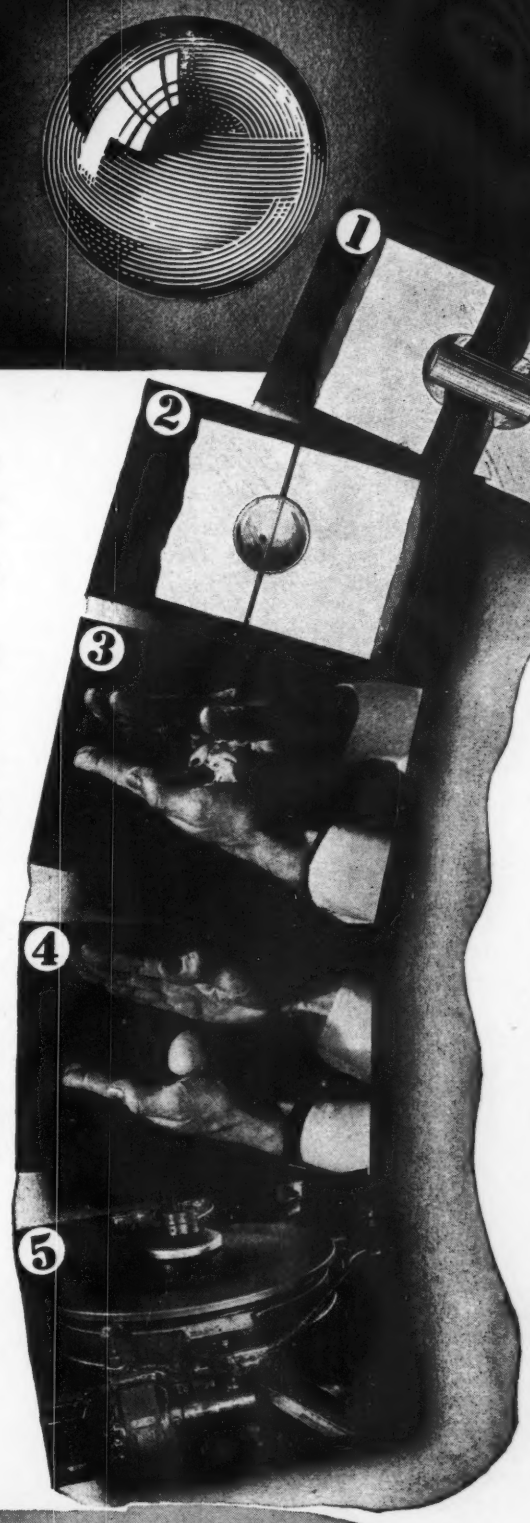
(*Continued from page 152*)

ings. One of the chief causes of failure in porous metal bearings is the oxidation of the contained oil causing a clogging of the porous structure of the metal. Copper acts as a catalytic agent in the oxidation of oil. The tendency of oil to oxidize is increased by increased temperature or pressure. This problem has been successfully attacked by blending a type of lubricating oil which is highly resistant to corrosion. However, powdered metal bearings made of iron have the advantage of producing no catalytic effect on the oxidation of lubricating oil. A more important advantage in the use of iron or iron-copper in the bearings is that they have greater strength to withstand higher bearing pressures. However, the iron bearings have generally less porosity than the bronze.

The Amplex Division of the Chrysler Corporation has placed on the market porous metal bearings made from alloyed aluminum powders. These aluminum bearings have strength comparable with porous bronze bearings and show a very great reduction in weight over bronze. This is of particular value to the aircraft industry where weight reductions are of the greatest importance. Aluminum bearings can be installed in aluminum housings where use of bronze or other metal bearings would cause electrolytic corrosion.

The role that powder metallurgy has played in the war cannot be fully revealed until after peace has come. Powder metallurgy cannot be expected to perform miracles, but we can be sure that its application will further industrial progress.

But how do they make 'em so ROUND?



While the steel ball is but one little part of a ball bearing, it's a most important part—and making it "round" is a most important and interesting process.

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1 Slug of steel wire is placed between accurately formed dies.

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3 & 4 Grinding to perfection of diameter and sphericity is done in very much the same way that human hands can roll a ball from a lump of putty.

5 Final grinding and lapping polishes sphere to a brilliant finish—not for "looks", but for *perfection* of form and size.

nothing rolls like a ball

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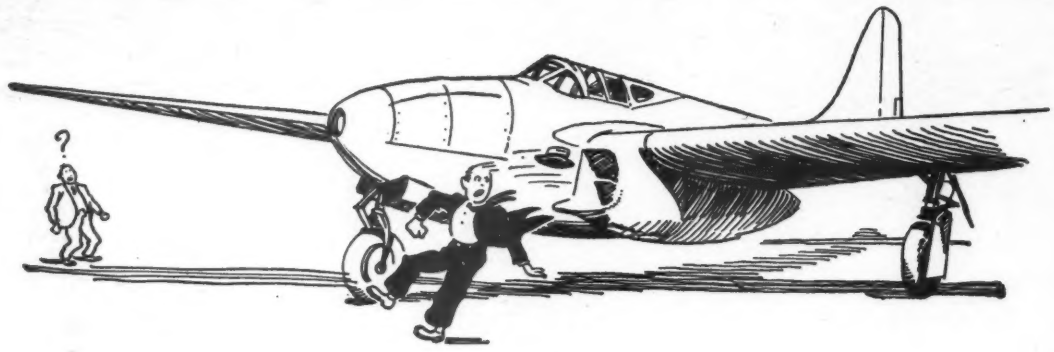
RESEARCH AND ENGINEERING KEEP GENERAL ELECTRIC YEARS AHEAD



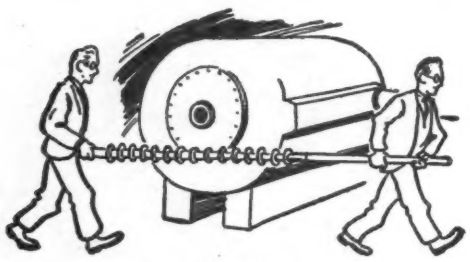
JET PROPULSION

QUICK on the take-off, prompt in answering the throttle, the jet-propelled plane has perhaps opened a revolutionary chapter in aviation. The P-59A Airacomet, built by Bell Aircraft, is the first American version—a single-seater, high-altitude fighter.

The engines were developed by General Electric from an original British design. The AAF assigned the job in 1941, and six months later the first jet engine in America, an aircraft gas turbine, was on test.

There's no propeller—reaction to a high velocity discharge of gases drives the plane forward. It's a practical application of Newton's law that "to every action there's an equal and opposite reaction."

The engine has only one main moving part. Air is taken into the engine, compressed, and after its temperature is increased by burning fuel, hot gases are discharged through a tailpipe nozzle. When these gases push in one direction, the plane moves in the other.



GIANT

THE new two million-volt X ray is the first one that can penetrate twelve inches of steel, and it can radiograph eight inches of steel 78 times as fast as the powerful million-volt units now on war jobs.

High voltage is supplied by a resonance transformer, a development of General Electric. Unlike the usual transformer, this has no iron core, and the X-ray tube is placed at its axis.

Since the new unit is strong enough to operate something like three feet away from the object, defects show on the film (behind the steel) in their actual size.

PHYSICS PLUS--

FOR a successful career in industrial physics a lot depends on a good background in English and chemistry. At least that's the opinion of Dr. Saul Dushman, assistant director of the G-E Research Laboratory.

This doesn't mean that a physicist has to be a "wielder of $64 words" or an orator on the side, but he'll go farther and get along better if he knows how to express himself clearly and correctly in his own language. And because he'll be working with newer and more complex materials, he'd better take chemistry too, says Dr. Dushman—all he can get. *General Electric Company, Schenectady 5, New York.*

Hear the General Electric radio programs: "The G-E All-girl Orchestra" Sunday 10 p.m. EWT, NBC—"The World Today" news, every weekday 6:45 p.m. EWT, CBS.

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